REPUBLIC OF RWANDA

Ministry of Infrastructure

Aviation Accident and Incident Investigation Division

Report on the serious incident to Boeing 737-700, 9XR-WJ

en route to Cape Town International Airport

Sept. 2nd 2018

The sole objective of investigations carried out by the AAID is the prevention of accidents and incidents. It shall not be the purpose of such an investigation to apportion blame or liability.

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List of Abbreviations used in this report

AMT	Aircraft Maintenance Technician
APU	Auxiliary Power Unit
ASR	Air Safety Report
ATC	Air Traffic Control
ATL	Aircraft Technical Log
Bite	Built-in test equipment
C/A	Cabin Attendant
DCPC	Digital Cabin Pressure Control
DFDR	Digital Flight Data Recorder
FIM	Fault Isolation Manual
FL	Flight Level
F/O	First Officer
ft	feet
ICAO	International Civil Aviation Organisation
kts	knots (nautical miles / hour)
MEL	Minimum Equipment List
MSA	Minimum Safe Altitude
NAI	Nacelle Anti-Ice
NG	New Generation
PA	Public Address
PFD	Primary Flight Display
PRSOV	Pressure Regulating and Shut Off Valve
RCAA	Rwanda Civil Aviation Authority
QRH	Quick Reference Handbook
TAI	Thermal Anti-Ice
UTC	Universal Time Coordinated

Synopsis

The Aviation Accident and Incident Investigation Division (AAID) became formally aware of this serious incident by a notification letter from the operator that was received on Sept 5th 2018, 3 days after the incident. In view of the potential safety lessons to be learnt the AAID Division Manager proposed an investigation to be carried out in accordance with the provisions of ICAO Annex 13.

The investigation into this serious incident is about a loss of cabin pressure and the subsequent emergency descent that occurred on flight WB 110 during the last portion of the cruise flight to Cape Town International Airport.

The investigation revealed that a similar pressurisation incident with the same aircraft occurred on June 7th 2017 while en route from Douala International Airport to Félix-Houphouët-Boigny International Airport near Abidjan.

As second main outcome significant deficiencies in communication within the organisation of the operator as well as between the operator and its contracted maintenance provider were found.

1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 General

Flight WB 110 on September 2nd 2018 was a scheduled passenger flight from Kigali International Airport (KGL) via Robert Gabriel Mugabe International Airport (HRE) at Harare to Cape Town International Airport (CPT) with a scheduled departure time of 06:20 UTC[1]. The flight was executed with a Boeing B737-700 carrying the registration 9XR-WJ.

The cockpit crew consisted of the Captain and the First Officer (F/O). The F/O was Pilot Flying on both stretches of flight WB 110.
The cabin crew consisted of the Purser, a senior Cabin Attendant and two additional Cabin Attendants (C/A's).

Apart from the cockpit and cabin crew, also the Aircraft Maintenance Technician (AMT), responsible for line maintenance activities and the technical release of the aircraft at KGL, HRE and CPT, travelled with flight WB 110.
At KGL also the chief maintenance supervisor supported the technical dispatch of flight WB 110.

1.1.2 Departure of flight WB 110 from Kigali International Airport

The 9XR-WJ aircraft had arrived in KGL at 05:09 on Sept. 2nd as flight WB 103 from O.R. Tambo International Airport (JNB) at Johannesburg. During this flight the crew noted a complaint in the Aircraft Technical Log (ATL) indicating that the right-hand TAI amber light[2] illuminated when Engine Anti-Ice was switched on.

[1] All times are indicated in UTC. Local time in KGL is UTC+2.
[2] TAI: Thermal Anti-Icing; when illuminated during flight, the TAI Amber Light indicates a malfunctioning cowl anti-ice valve.

Besides, the aircraft carried a deferred defect concerning the right-hand pneumatic High Stage valve. This valve had been found defective on Sept 1st. Because of lack of spares, it was locked in the closed position according to the applicable procedure from the Minimum Equipment List (MEL).

After the crew had boarded the aircraft to perform their pre-flight duties for flight WB 110, the Captain checked the complaint from the incoming flight regarding the illumination of the right-hand TAI light. Because of this complaint he requested the AMT to lock the right-hand cowl anti-ice valve in the open position according to the applicable MEL procedure.

Subsequently the AMT explained to the Captain that the right-hand TAI amber light had illuminated at a low engine power setting during taxi-in. The AMT stated that this condition, in combination with the right-hand High Stage valve being locked in the closed position, creates insufficient air flow for the Nacelle Anti-Ice (NAI) valve to open. Thus, according to the AMT, the illumination of the TAI amber light had been normal system behaviour.

The possible illumination of the TAI amber light at low power settings when the related High Stage valve is locked closed, is not mentioned in the applicable MEL procedure, nor in the QRH procedure on the TAI amber annunciation.

Initially, because of the ongoing discussion about the technical status of the aircraft, the passengers were denied boarding. From the interviews with all concerned, it transpired that the communication between the maintenance crew and the cockpit crew caused irritation on both sides. At some stage the F/O left the cockpit to discuss matters with the chief maintenance supervisor on the apron, since there was disagreement about the point of time for the passengers to board the aircraft.

Since the Captain wanted to have confirmed that the right-hand NAI valve was serviceable, the AMT positioned the right-hand Pressure Regulating and Shut Off Valve (PRSOV) temporarily to the open position according to the applicable procedure from the Fault Isolation Manual (FIM). Through this procedure

pneumatic pressure from the Auxiliary Power Unit (APU) reaches the NAI valve, thus enabling verification of its operation when the engine is not running (see Appendix 1 for the related pneumatic schematic).
This task was performed successfully and documented in the Aircraft Technical Log (ATL).

The decision to carry out the above mentioned PRSOV procedure required the engine cowls to be opened again while the passengers already had boarded the aircraft.
After closing of the engine cowls and signing the release to service, flight WB 110 departed with a delay of 1:34 hours at 07:54.

1.1.3 Flight to Harare

All crewmembers stated in their interviews that, after the delayed departure from KGL, flight WB 110 to HRE was uneventful. On the stretch KGL-HRE no complaints were entered in the ATL.

1.1.4 Ground stop at Harare

At Harare, the passengers with destination HRE disembarked whereas others joined the flight to CPT. As on the stretch KGL-HRE, the economy class of the flight from HRE to CPT was almost fully booked.
The ground stop revealed no particulars, flight WB 110 departed HRE at 11:27.

1.1.5 Flight to Cape Town

All interviewees indicated that the departure from HRE as well as the first portion of the cruise flight to CPT were uneventful.
During the last part of the cruise flight, the cockpit crew made a step descent from FL 400 to FL 380 to avoid some light turbulence. Then, at FL 380, the right-hand Bleed Trip Off light illuminated as was indicated by both pilots. Subsequently the crew performed the applicable procedure from the Quick Reference Handbook (QRH). The First Officer (F/O) indicated during his interview that the Bleed Trip Off light could not be reset, which requires the right-hand air-conditioning pack to be switched off (see Appendix 2 for the applicable QRH procedure). From the Digital Flight Data Recorder (DFDR) it

could be established that the right-hand pack valve was closed as from 13:54:43[3]. At the same time the left-hand pack switched conform system design from the 'Low Flow' to the 'High Flow' mode.
The illumination of the right-hand Bleed Trip Off light was not entered in the Aircraft Technical Log (ATL).

Emergency descent from cockpit perspective

DFDR data show that some 4:30 minutes later, at 13:59:10, the cabin altitude warning was activated, indicating that the cabin altitude had risen above 10.000 ft. The captain stated in his interview that, upon triggering of the cabin altitude warning, he checked the cabin altimeter on the overhead panel indicating 10.500 ft[4]. He therefore decided to perform an emergency descent without delay.

The crew donned their oxygen masks and deployed the cabin oxygen masks by actuating passenger oxygen switch on the overhead panel according to the applicable procedure from the QRH (see Appendix 4). This procedure amongst others calls for selecting the outflow valve manually to the full closed position. During his interview the F/O stated that, when doing so, he found the outflow valve already to be in the full closed position.

Meanwhile the Captain announced 'emergency descent, emergency descent, emergency descent' through the Public Address (PA) system and, after coordination with the South African Air Traffic Control (ATC) initially selected 12.000 ft as target altitude for level-off. During the descent transponder code 7700[5] was selected, together with the issuance of a MayDay call.
According to the Captain the cabin pressurisation was under control again when passing FL 240. Therefore it was decided to stop the descent at FL 180 and to continue the flight to CPT at that level.

[3] Detailed DFDR data can be found in Appendix 3.
[4] Activation of the cabin altitude warning is the only pressurisation parameter that is registered on the DFDR. Cabin altitude and outflow valve position are not recorded.
[5] As laid down in international standards, selecting of transponder code 7700 will alert ATC that a flight has encountered an emergency situation.

The Captain then made another PA announcement, indicating that the situation was under control and that the passengers and crew could take their masks off.

Both pilots indicated that ATC did a professional job in coordinating the emergency descent with flight WB 110. Since at the time of the emergency descent no traffic in the vicinity of flight WB 110 was operating, potential conflicts with other flights were no factor.

Emergency descent from cabin perspective

Next to the Captain and F/O, interviews were held with the entire cabin crew of flight WB 110. All indicated that the flight had been progressing normally until, as stated by the purser, “the oxygen masks dropped down from nowhere”, followed by the PA announcement ‘emergency descent’ by the Captain. At that time all catering trolleys were stowed in the galleys, since the cabin service just had been terminated. Most comments from the interviews indicated that the descent was conducted in a relatively smooth manner, one C/A indicated it was a “sharp descent”. The cabin crew secured themselves and put on their oxygen masks. They indicated that the passengers remained calm and used their oxygen masks, thereby helping each other. One infant refused to take the mask, her mother had to force her to.

After the second PA announcement from the Captain indicating that the situation was under control, the cabin crew took the portable oxygen bottles and checked the state of all passengers. All appeared to be in good condition. A few passengers were upset, but in general the atmosphere in the almost fully booked cabin was calm.

Some passengers complained that their mask had not been delivering oxygen. The purser indicated that this probably was due to fact that the mask was not sufficiently pulled downwards to release the pin and thus to start the flow of oxygen.

Shortly after the second PA announcement the purser went to the cockpit to brief the pilots about the situation in the cabin being normal and under control.

Information obtained from the interviews and the operator disclosed that during the flight safety training for cabin crew no simulator is used. Preparation for handling an emergency descent is trained in the classroom and during a visit to the aircraft.

Approach and landing at Cape Town

Flight WB 110 landed at CPT without further anomalies at 14:43. After the passengers had disembarked, the Captain debriefed the cabin crew on the emergency descent in the business section of the cabin.
The Captain also wrote and submitted an occurrence report on the events during flight WB 110 to inform the operator; the relevant text from this report in incorporated as Appendix 5.

1.1.6 Ferry flight from Cape Town to Kigali

According to an interview held with maintenance staff at KGL after the incident, a pressurisation and a pneumatic health check were performed after arrival of flight WB 110 at CPT. It was stated that during these checks, apart from the defective right-hand High Stage valve, no irregularities were found.
The carrying out of the pressurisation and pneumatic health checks is not documented in the ATL. The relevant ATL coupon (see Appendix 6) states that a Bite check[6] was performed on both Digital Cabin Pressure Control (DCPC) units. This Bite check revealed no particulars where after the AMT released the aircraft for service.
Subsequently it was decided that the crew, originally scheduled to operate flight WB 111 back to Kigali with a transit stop at HRE, would now fly the 9XR-WJ aircraft directly to KGL without passengers. The entire cabin crew travelled on the ferry flight as well. It was verified that sufficient oxygen masks for them were available. The captain who was operating the ferry flight stated that the 9XR-WJ has had several pneumatic issues in the past, he therefore decided to limit the altitude for the flight to FL 250.

[6] 'Bite' or 'Built-in test equipment' is part of a system that monitors the correct functioning of that system.

The ferry flight departed from CPT at 18:56 and arrived at KGL at 00:52 on Sept. 3rd uneventfully.

1.5 Personnel information[7]

The cockpit crew of flight WB 110 consisted of a Captain and First Officer. Both were qualified to fly B737-NG aircraft and had a valid medical certificate.

1.5.1 Captain

Age:	56 years
Licence type:	ATPL
Date of issue:	18/06/2018
Valid until:	30/05/2019
Medical certificate valid until:	14/06/2019
Total flying experience	18000
Total flying experience on type	10400

1.5.2 First Officer

Age:	46 years
Licence type:	ATPL
Date of issue:	30/08/2018
Valid until:	30/05/2019
Medical certificate valid until:	06/06/2019
Total flying experience	7700
Total flying experience on type	2700

[7] This report follows the paragraph numbering according to Appendix 1 of ICAO Annex 13. Paragraphs numbers that are not listed, are not applicable to this investigation.

1.6 Aircraft information

Manufacturer	Boeing Commercial Airplanes
Type	Boeing 737-700
Registration	9XR-WJ
Engines	Engine #1 S/N:963375 Engine #2 S/N:892479
Date of manufacture	01/04/2007
Certificate of airworthiness	Due date: 30/04/2019
Last maintenance check	Engine #2 replacement done on 31st Dec. 2018

1.7 Meteorological information

Meteorological aspects had no bearing on the course of the incident.

1.9 Communications

Both pilots indicated that South African ATC was helpful and professional in their coordination with flight WB 110 during and after the emergency descent.

1.11 Flight recorders

For the conduct of this investigation all data from the DFDR of flight WB 110 were available. These data are monitored on a regular basis by an external provider in a flight data management programme. From these data the execution of the emergency descent could be presented in a 3D animation.

The external provider alerts the airline concerned when irregularities or exceedances during a flight occur. Such irregularities or exceedances are presented as 'events', categorised as level 1, 2 or 3, whereby level 3 represents the highest risk category. At the time of the incident, triggering of the cabin altitude warning was not incorporated in the monitoring programme of the external provider, thus no alert was generated. During the course of this investigation activation of the cabin altitude warning horn was incorporated as a level 3 event in the monitoring programme of the provider as yet.

Further it should be noted that the current flight data monitoring programme does not comprise an event definition for the execution of an emergency descent. The rapid descent from FL 380 to FL 180 of flight WB 110 was therefore not registered as an event about which the operator was to be informed.

The DFDR data from flight WB 110 were also read out by the maintenance contractor based in Addis Abeba, Ethiopia. An overview of the relevant DFDR data can be found in Appendix 3. It must be noted here that, with regard to cabin pressurisation, activation of the cabin altitude warning horn is the only available parameter[8]. The actual cabin altitude and the outflow valve position are not recorded.

1.16 Tests and research

The B737-NG (New Generation) fleet of the operator consists of 6 aircraft: 4 x B737-800's and 2 x B737-700's. The latter ones are registered as 9XR-WJ, being the aircraft involved in this investigation, and 9XR-WK. The technical performance, including parameters like dispatch reliability, are monitored on a monthly basis by means of a 'Reliability Report B737-NG'.

During the investigation many flight crew members indicated that operation of the 9XR-WJ aircraft, in comparison with the 9XR-WK aircraft, was characterised by a large number of technical problems related to 'pneumatics' and 'air conditioning', see also paragraph 1.17 below. It was therefore decided to review the monthly reports over the past year, from Oct. 2017 till Sept. 2018, thereby assessing the performance of the WJ against the WK aircraft with regard to the subjects 'pneumatics' and 'air conditioning'. From this review it followed that during that year the WJ had a total of nine pneumatic and/or air conditioning related issues, whereas the WK had none. The nine issues on the WJ aircraft all transpired between February 2018 and September 2018.

[8] The cabin altitude warning horn is activated when the cabin altitude exceeds 10.000 ft.

The overall dispatch reliability[9] of both B737-700 aircraft as derived from the monthly reliability reports, is depicted in the table below:

Dispatch reliability percentage			
Month & year		**9XR-WJ**	**9XR-WK**
October	2017	99.15	100.00
November	2017	98.15	100.00
December	2017	99.32	100.00
January	2018	99.32	100.00
February	2018	97,58	100.00
March	2018	99.37	100.00
April	2018	99.32	100.00
May	2018	98.85	100.00
June	2018	99.43	100.00
July	2018	98.73	100.00
Augustus	2018	100.00	100.00
September	2018	98.84	100.00

After it became apparent that at the time of the incident activation of the cabin altitude warning did not trigger an alert in the flight data management programme (see paragraph 1.11), the external provider in charge of this programme was asked to check on the cabin altitude parameter for the 9XR-WJ aircraft over the past two years.

From this query it followed that from Oct. 4th 2016 till Oct. 29th 2018 no additional similar events had occurred on the WJ aircraft.

However, at a later stage of the investigation it was found that a similar incident during operation of the WJ aircraft transpired on June 7th 2017. The main facts and conditions of this incident are summarised below:

[9] The dispatch reliability is defined as follows: The percentage of scheduled flights started and completed without an interruption (cancellation, air turn back, diverted landing, or delay greater than 15 minutes) chargeable to an airplane system or component primary malfunction (not secondary or consequential).

- Flight WB 222 on June 7th 2017 was conducted with the 9XR-WJ aircraft. The scheduled routing for flight WB 222 was: Kigali (KGL) - Libreville (LBV) - Douala (DLA) - Abidjan (ABJ).

- Flight WB 222 departed from KGL with a deferred defect concerning illumination of the right-hand Bleed Trip Off light.

- According to the MEL, dispatch with a Bleed Trip Off light is possible only when the maximum cruise altitude is restricted to FL 250.

- During cruise flight at FL 380 between DLA and ABJ the cabin altitude warning was triggered. According to the ASR, drawn-up by the captain, the cabin altitude was uncontrollable. As a result an emergency descent was made, including presentation of the oxygen masks in the cabin, where after the flight diverted to Cotonu (COO).

- After the decompression incident on June 7th 2017, maintenance follow-up took place on June 12th 2017. At this occasion the right-hand precooler valve and the left-hand PRSOV were replaced.

1.17 Organisational and management information

The operator of flight WB 110 has outsourced its aircraft maintenance activities to a contractor, based in Addis Abeba, Ethiopia. The AMT, who travelled with flight WB 110 and signed for the maintenance release in KGL, HRE and CPT, and the chief maintenance supervisor based at KGL were employed by the operator.

During the interviews with all parties concerned, the interviewees indicated on several occasions that a lack of communication and mutual trust between the maintenance team and the flight operational crews exists.
Many flight crew members stated that the 9XR-WJ aircraft has a history of repetitive pneumatic complaints. They indicated amongst others that there must have been at least two or three similar pressurisation related events, like the one of flight WB 110, that occurred over the past year.

Apart from an occasional e-mail from the technical pilots, flight crews are not informed on the follow-up of technical incidents on a regular basis. The operator does not issue a safety bulletin to its crews. Also a lack of response to occurrence reports, submitted by flight crews, was indicated.

The maintenance team at KGL organises a morning briefing three times a week. Initially these briefing were attended by a technical pilot. These days the technical pilots no longer participate in the maintenance morning briefings.

1.18 Additional information

On several parts of the routing from HRE to CPT and CPT to KGL the minimum safe altitude (MSA) is above 10.000 ft[10]; on some parts the MSA is above 14.000 ft, see Appendix 7.

[10] A cabin altitude of 10.000 ft or more requires the use of oxygen by the cockpit crew; a cabin altitude above 14.000 ft requires the use of oxygen for everyone on board.

2. ANALYSIS

2.1 Departure of flight WB 110 from Kigali

Prior to departure from KGL, the WJ aircraft carried two technical complaints: one deferred defect, indicating that the right-hand High Stage valve was locked in the closed position, and one ATL entry from the incoming flight. This ATL entry concerned a right-hand TAI[11] amber annunciation when engine anti-ice was switched on. The text did not indicate during which phase of flight the TAI annunciation occurred, but from interviews it became apparent that the light came on during taxi-in at KGL.

From the pneumatic system overview in Appendix 1 it can be seen that, when the right-hand High Stage valve is closed in combination with the low power setting during taxi-in, there will be insufficient pneumatic pressure to open the Nacelle Anti-Ice valve once it is selected ON in the cockpit. As a consequence the associated amber NAI annunciator will illuminate. Thus, under the prevailing circumstances the illumination of the right-hand TAI annunciator light must be considered as normal system behaviour, as was indicated by the AMT.
It must however be noted that the possibility of such a nuisance indication is not mentioned in the MEL procedure for a deactivated High Stage valve, nor in the Quick Reference Handbook (QRH). Therefore the cockpit crew had no possibility to verify the statement from the AMT that the ATL entry could be disregarded.

From the interviews it clearly transpired that amongst cockpit crews there is lack of trust in support from the contracted maintenance team. Besides crews did indicate that the WJ carried a reputation of having technical problems with the pneumatic system (see also paragraph 2.6, Organisational and human factors). These aspects, together with the cockpit crew not being aware of a possible nuisance TAI warning, make it understandable that the Captain initially did not accept the explanation from the AMT. Instead the Captain

[11] TAI: Thermal Anti-Icing

demanded that proper operation of the right-hand NAI valve would be demonstrated to him. This demand required temporary opening of the PRSOV, which is a quite cumbersome procedure requiring opening of the engine cowls.

From the above it comes to no surprise that the communication between the cockpit crew on the one hand and the AMT and chief maintenance supervisor on the other can be characterised as troublesome, causing annoyance on both sides.

2.2 Illumination of the right-hand Bleed Trip Off light

During cruise flight between HRE and CPT the right-hand Bleed Trip Off light illuminated. The crew indicated that the light could not be reset. This is an indication that the temperature from the bleed air that is extracted from the right-hand engine has become too hot. As a safety precaution all bleed air from the affected engine is then shut-off. Engine bleed air is amongst others used for the pressurisation of the cabin. Illumination of the Bleed Trip Off light therefore means halving of the pneumatic supply to both air conditioning packs that pressurise the cabin. In view of the loss of pneumatic supply, the affected pack valve should be switched off where after the remaining pack switches from 'Low Flow' to 'High Flow' to compensate for the lost bleed air source.

From the interviews with the cockpit crew and the DFDR data, that show the switching-off of the right-hand pack at time 13:54:43, it may be concluded that the applicable QRH procedure was correctly followed and that subsequently the left-hand pack switched from 'Low' to 'High Flow' as per system design.

The crew did not make an entry in the ATL about the illumination of the Bleed Trip Off light. As a result no maintenance follow-up on this technical complaint was documented. Besides, an omission to enter a complaint also hampers proper trend analysis on technical performance. Bearing in mind the disputed

reputation on pneumatic issues of the WJ aircraft, proper documentation of complaints is of even more importance.

2.3 Activation of the cabin altitude warning horn and emergency descent

DFDR data indicate that 4:30 minutes after switching off the right-hand pack as prescribed in the QRH procedure, the cabin altitude warning started to sound.
All available data demonstrate that this warning was a genuine one, indicating that the cabin altitude indeed had increased above the limit of 10.000 ft.
It is justified to conclude that adequate cabin pressure could not be maintained at FL 380 while flight WB 110 was operating on one bleed and one pack in the 'High Flow' mode.
Meaningful to this respect was a remark from the F/O: when the applicable depressurisation procedure from the QRH called for manual closing of the outflow valve, he found that the outflow valve already had been regulated towards the full closed position[12].

During the investigation it became apparent that different views existed on the requirement to manually deploy the oxygen masks in the cabin by pressing the PASS OXYGEN switch on the overhead panel in the cockpit.
Since, upon triggering of the warning, the cabin altitude was indicating 10.500 ft (as indicated by the Captain) and the outflow valve already was in the full closed position (as indicated by the F/O), the conclusion from the crew that the cabin altitude was uncontrollable, was correct. The statements from the cockpit crew are supported by the fact that the cabin altitude warning horn kept on sounding for 4:41 min. even though the emergency descent was initiated without delay. Based on the above, and the relevant part from the

[12] The outflow valve regulates the air flow from the cabin to the ambient atmosphere. Normally the outflow valve position is automatically regulated by the pressurisation controllers. When the cabin altitude increases above the target value, the valve will be regulated towards the closed position. Finding the valve in the full closed position is therefore an indication that the aircraft systems were no longer capable of maintaining adequate pressure in the aircraft cabin.

QRH procedure depicted below, it follows that the decision to deploy the oxygen masks manually, was correct.

1 Don oxygen masks and set regulators to 100%.

2 Establish crew communications.

3 Pressurization mode selector . . . . . .MAN

4 Outflow VALVE switch . . . . . .Hold in CLOSE until the outflow VALVE indication shows fully closed

5 **If** cabin altitude is **uncontrollable**:

Passenger signs . . . . . .ON

PASS OXYGEN switch . . . . . .ON

►►**Go to the Emergency Descent checklist on page 0.1**

All available data indicate that the subsequent emergency descent was performed in a professional way and according to company procedures. This was confirmed by the 3D animation from the flight data management programme, supplied by the contracted external provider. As an illustration a screen print from the flight instruments during the descent is incorporated as Appendix 8.

Also from cabin perspective the emergency descent, though it came as a surprise to the cabin crew, was handled well. Some cabin crewmembers however indicated that they would have valued more practical training in dealing with a situation like an emergency descent by use of a simulator.

Chapter 4 of the company's Operations Manual contains a detailed and comprehensive training programme for cabin crewmembers, including practical training in fire-fighting and ditching. While the Manual mentions the possibility to use 'an approved simulator' several times, other emergency situations, such as an emergency descent, are currently trained in the classroom supplemented by a limited time for familiarisation on the aircraft. Although using the actual aircraft formally is an approved practice, it is advisable that the operator reconsiders the practical training aspects for their cabin staff, e.g. by use of a simulator.

2.4 Maintenance release at Cape Town

The performing of a Bite check with a satisfactory result is the only documented maintenance action at CPT. Based on this satisfactory Bite check the aircraft was released to service by the AMT.
As indicated in paragraph 2.2, the ATL contains no information or follow-up on the illumination of the unresettable amber right-hand Bleed Trip Off light.

All data acquired during the investigation unambiguously demonstrate that adequate cabin pressure could not be maintained at FL380 while operating on one bleed and one pack in the 'High Flow' mode. The illumination of the Bleed Trip Off annunciator must therefore be considered as a precursor of the cabin altitude warning and the subsequent emergency descent.

Based on the above it must be concluded that the release to service at CPT was signed on incorrect grounds.

2.5 Ferry flight from Cape Town to Kigali

Since at CPT replacement of the used cabin oxygen generators was not possible, a ferry flight without passengers direct to KGL was conducted. It was adequately verified that oxygen supply for both the cockpit and cabin crew was assured.
Although not prescribed by any procedure, the captain decided to limit the altitude for the flight to KGL to FL 250 because of lack of confidence in the pneumatic and pressurisation system of the WJ aircraft. While this can be considered as a prudent precaution, it is yet another indication of the lack of trust from flight crews in the support by the maintenance team.

2.6 Organisational and human factors

In paragraph 1.16, Tests and research, an overview is given of the technical complaints related to pneumatics and air conditioning as well as the dispatch reliability of both the WJ and the WK aircraft. From this overview it can be concluded that the WJ indeed has shown more technical issues, especially over the last 8 months prior to the incident on Sept. 2nd 2018, but that the performance of the WJ still has been satisfactory with an overall dispatch reliability rate of 98% or better.

Based on the statement of several flight crew members that the WJ aircraft was involved in 'at least two or three similar incidents', the investigation team looked further into the technical history of the WJ aircraft. It was then found that a highly similar pressurisation incident occurred on June 7th 2017 en route from Douala (DLA) to Abidjan (ABJ) as documented in paragraph 1.16, Tests and research. The most concerning finding from this occurrence is that the flight between DLA and ABJ was conducted at FL 380, whereas the applicable MEL procedure for an illuminated Bleed Trip Off light prescribes a maximum altitude of FL 250.

These aspects, and several other pointers in this investigation, such as the circumstances around the delayed departure of flight WB 110 from KGL, indicate a disturbed relationship between the maintenance team and flight crews. This disturbed relationship not only was a factor in this incident but also will have a negative bearing on the safety culture within the entire company.

Carefully organised regular contacts between maintenance and flight crews through meetings and safety bulletins, as well as timely feedback on submitted Air Safety Reports (ASR's), will objectify speculations and re-institute a sound cooperation between parties. This is an essential element for the long term safety performance of the operator, even more so since the maintenance team and flight crews belong to two different companies.

2.7 Maintenance follow-up after the pressurisation incident

As far as could be established, maintenance actions have not revealed a specific cause for the cabin pressure loss of flight WB 110. As indicated in the QRH, the use of wing ant-ice above FL 350 when flying on one bleed source could result in cabin pressure loss. There was however no operational need to use wing anti-ice, moreover DFDR data confirm that the wing anti-ice switch was in the OFF position during the entire flight. The possible factors leading up to the cabin pressure loss are thus confined to:

- Insufficient supply from the left-hand pneumatic system, caused by malfunctioning components or leak(s),
- Insufficient supply from the left-hand pack operating in 'High Flow' mode, caused by malfunctioning components or leak(s),
- A too large natural leak from the pressure cabin, e.g. caused by flaws of (cargo)door seals or faults in the outflow valve.

Obviously a combination of the above mentioned factors would be a last possibility. To safeguard that a similar incident on the WJ aircraft does not re-occur when flying at high altitude on one bleed source only, the operator should ensure a thorough check on the above mentioned factors and seek, through their contracted maintenance party, expertise via Boeing Field Service where needed. This approach is of even more importance when bearing in mind the highly similar incident that happened on the same aircraft on June 7th 2017.

3. CONCLUSIONS

3.1 Findings

3.1.1 The crew was properly licensed and qualified to perform the flight.

3.1.2 Prior to departure from KGL the Aircraft Flight Log comprised a deferred defect and a complaint, both related to the right-hand pneumatic system.

3.1.3 During handling of the complaint concerning the right-hand Thermal Anti-Ice annunciation, misunderstanding and annoyance between the maintenance team and the cockpit crew arose.

3.1.4 The possible nuisance illumination of the Thermal Anti-Ice amber light at lower power settings when the related High Stage valve is locked closed, is not documented.

3.1.5 As a result of the above, flight WB 110 left KGL with a delay of 1:34 hours.

3.1.6 During the last portion of the cruise flight from HRE to CPT at FL380, the right-hand Bleed Trip Off light illuminated and initially could not be reset.

3.1.7 The crew followed the procedure concerning the illumination of the Bleed Trip Off light correctly.

3.1.8 No entry in the Aircraft Technical Log concerning the illumination of the Bleed Trip Off light was made.

3.1.9 4:30 min. after illumination of the Bleed Trip Off light, the cabin altitude warning was activated.

3.1.10 The crew correctly concluded that the cabin altitude was not controllable and started an emergency descent without delay.

3.1.11 The emergency descent procedure was correctly followed by both the cockpit and the cabin crew.

3.1.12 Currently cabin crew training for an emergency descent is conducted in the classroom and by a visit to the aircraft.

3.1.13 Some passengers indicated that their oxygen mask had not been supplying oxygen.

3.1.14 The South African Air Traffic Control was helpful and professional in their coordination during and after the emergency descent.

3.1.15 The only documented maintenance action at CPT was the execution of a Bite check on both pressurisation controllers of the aircraft.

3.1.16 Since the illumination of the right-hand Bleed Trip Off light had not been entered in the Aircraft Technical Log, no maintenance follow-up on this complaint took place.

3.1.17 Signing of the Maintenance Release at CPT was done on incorrect grounds.

3.1.18 Since the cabin oxygen generators could not be replaced at CPT, a ferry flight direct to KGL without passengers was conducted.

3.1.19 The ferry flight from CPT to KGL was conducted at FL 250.

3.1.20 Initially the external provider had not incorporated an alert in their standard flight data management programme to warn the operator for a cabin altitude warning.

3.1.21 During the course of this investigation the external provider has incorporated an alert in their standard flight data management programme to warn the operator for a cabin altitude warning as yet.

3.1.22 The current flight data management programme does not comprise an event definition for an emergency descent.

3.1.23 B737NG pilots indicated that the 9XR-WJ aircraft had a reputation of having pneumatic problems and that more similar depressurisation events had occurred over the past two years.

3.1.24 Research revealed that the 9XR-WJ aircraft has had nine pneumatic complaints from Febr. 2018 till Sept. 2018, but still had a dispatch reliability score above 98%.

3.1.25 During the investigation it became apparent that the 9XR-WJ aircraft was involved in a highly similar pressurisation incident on June 7th 2017 while en route from Douala to Abidjan.

3.1.26 The operator does not inform its flight crews on follow-up of safety occurrences on a regular basis.

3.1.27 Contact between technical pilots from the operator and the contracted maintenance team is not organised on a regular basis.

3.1.28 Pilots have indicated a lack of response after submitting safety occurrence reports.

3.1.29 The deficient communication between flight crews and the maintenance team has resulted in lack of trust and a disturbed relationship between the two parties, affecting the safety culture within the organisation of the operator.

3.1.30 After the incident it has not unambiguously been demonstrated that the 9XR-WJ aircraft will sustain adequate cabin pressure when flying on one bleed and one pack operating in 'High Flow' at FL 380 or higher.

4. SAFETY RECOMMENDATIONS

4.1 The operator is recommended to inform its B737NG cockpit crewmembers that illumination of the Thermal Anti-Ice amber light at lower power settings when the related High Stage valve is locked closed, should be considered as normal system behaviour.

4.2 The operator is recommended to explicitly communicate to flight crews the importance of careful and complete logging of any technical complaint in the Aircraft Technical Log.

4.3 The operator is recommended to (re)introduce the use of a simulator for training of cabin crewmembers to enhance their preparedness for handling emergency situations like loss of cabin pressurisation.

4.4 The operator is recommended to review the current flight safety instruction to passengers thereby clarifying and emphasising that oxygen masks, when presented, need to be pulled downwards firmly to activate the flow of oxygen.

4.5 The operator is recommended to instruct the external provider supplying the flight safety management programme to define a safety event that will generate an alert in case of a rapid (emergency) descent.

4.6 The operator is recommended to take managerial steps in structurally improving communication between flight crews and maintenance, e.g. by issuing feedback on safety occurrences on a regular basis and re-establishing regular contacts between technical pilots and the maintenance team.

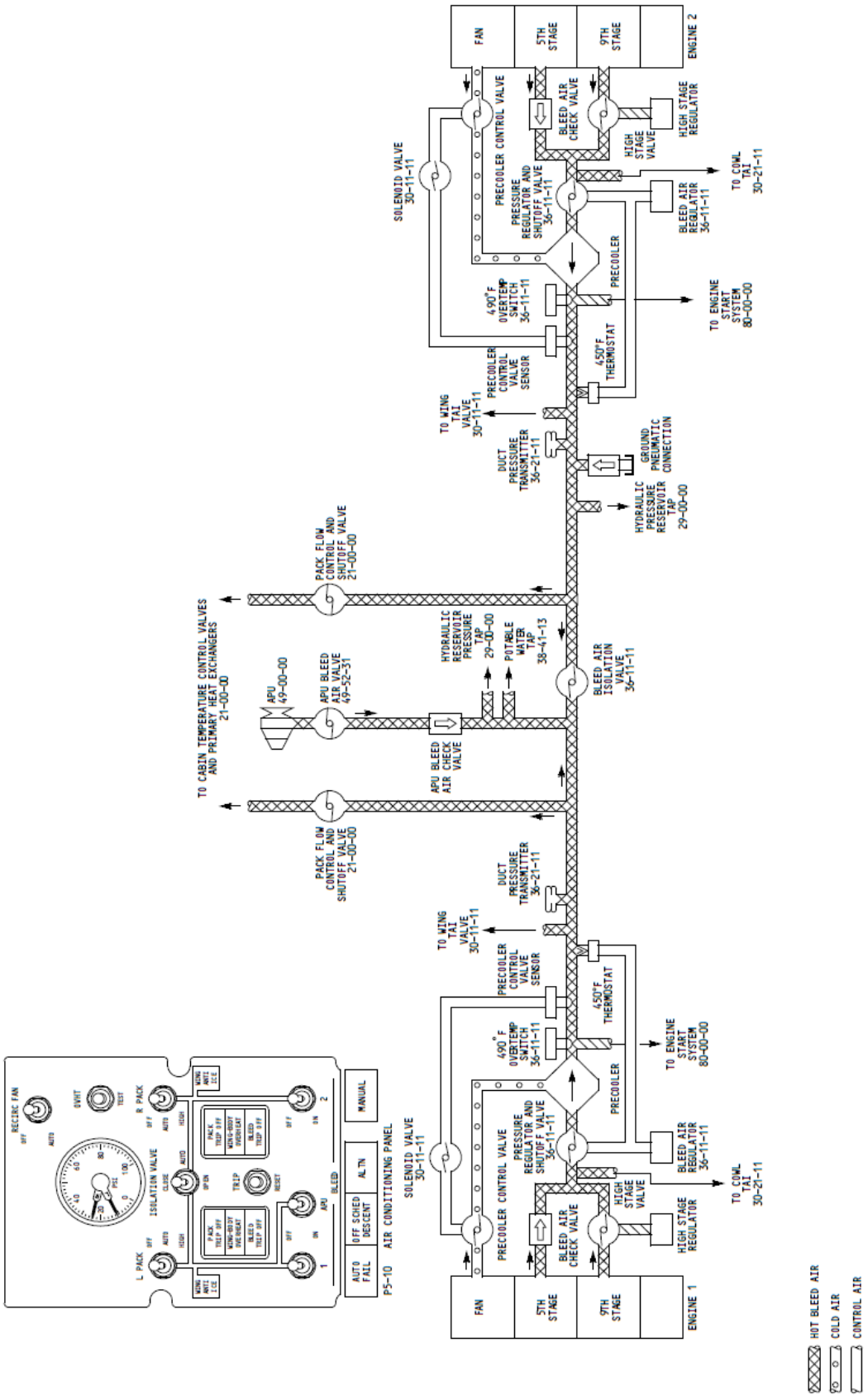
4.7 The operator is recommended to safeguard that pilots receive feedback on submitted safety occurrence reports in an effective and timely manner.

4.8 The operator is recommended to demand from its maintenance contractor to unambiguously demonstrate that the 9XR-WJ aircraft will sustain adequate cabin pressure when flying on one bleed and one pack operating in 'High Flow' at FL 380 or higher.

4.9 Considering both pressurisation incidents involving the same aircraft, Rwanda Civil Aviation Authority (RCAA) is recommended to intensify their oversight on adequate follow-up after repeated operational occurrences.

5. APPENDICES

Appendix 1: schematic pneumatic system B737-700



Appendix 2: Bleed Trip Off light procedure from QRH

BLEED TRIP OFF

BLEED TRIP OFF

Condition: One or more of these occur:
- An engine bleed air overheat
- An engine bleed air overpressure.

1 WING ANTI-ICE switch . . . . . OFF

2 TRIP RESET switch . . . . . .Push

The BLEED TRIP OFF light extinguishes if the bleed air temperature has cooled below limits.

3 Choose one:

◆BLEED TRIP OFF light **stays illuminated**:

PACK switch (affected side) . . . . . OFF

This causes the operating pack to regulate to high flow in flight with flaps up.

Avoid icing conditions where wing anti-ice is needed.

■ ■ ■ ■

◆BLEED TRIP OFF light **extinguishes**:

►►**Go to step 4**

4 WING ANTI-ICE switch . . . . . .As needed

Caution! Use of wing anti-ice above approximately FL350 may cause bleed trip off and possible loss of cabin pressure.

■ ■ ■ ■

Appendix 3: DFDR data overview

Sample	Air/Grnd	GMT	MastCaut	CabAlt>10K	ECSPackOn-L	ECSPackOn-R	ECSPackFlw-L	ECSPackFlw-R	BleedSw-1	BleedSw-2
	Note: parameters that have an abnormal value for the phase of flight are indicated in Red									
HRE - CPT: normal system behaviour until sample 72879										
72878	AIR	13:54:40	No Warn	No Warn	ON	ON	Low	Low	ON	ON
72879	AIR	*13:54:41*	No Warn	No Warn	ON	ON	Low	Low	ON	ON
From sample 72880 ECSPackFlw-R indicates 'Off/High' instead of 'Low'										
72880	AIR	*13:54:42*	No Warn	No Warn	ON	ON	Low	**Off/High**	ON	ON
From sample 72881, thus one sec. later, ECSPackOn-R indicates 'Off' instead of 'On'										
72881	AIR	*13:54:43*	No Warn	No Warn	ON	**Off**	Low	**Off**/High	ON	ON
From sample 72882, thus one sec. later, also ECSPackFlw-L starts indicating 'Off/High' instead of 'Low'										
72882	AIR	13:54:44	No Warn	No Warn	ON	**Off**	Off/**High**	**Off**/High	ON	ON
From sample 73148 also the CabAlt>10K is triggered										
73148	AIR	*13:59:10*	No Warn	**WARN**	ON	**Off**	Off/**High**	**Off**/High	ON	ON
From sample 73159 all pack indications are normal again, with CabAlt>10K still active										
73159	AIR	*13:59:21*	No Warn	**WARN**	ON	**ON**	**Low**	**Low**	ON	ON
From sample 73430 CabinAlt>10K stops (thus the warning has been active for 4:41 min.)										
73430	AIR	14:03:51	No Warn	**No Warn**	ON	ON	Low	Low	ON	ON
From sample 74263 ECSPackOn-R and ECSPackFlw-R again show 'Off' and 'Off/High' respectively										
74263	AIR	*14:17:44*	No Warn	No Warn	ON	**Off**	Low	**Off**/High	ON	ON
From sample 74264, thus one sec. later, also ECSPackFlw-L shows 'Off/High'										
74264	AIR	*14:17:45*	No Warn	No Warn	ON	**Off**	Off/**High**	**Off**/High	ON	ON
From sample 74380 both ECSPackFlw indications return to 'Low'										
74380	AIR	*14:19:41*	No Warn	No Warn	ON	**Off**	**Low**	**Low**	ON	ON
From sample 74381, thus one sec. later, ECSPackOn-R starts indicating 'ON' again;										
74381	AIR	*14:19:42*	No Warn	No Warn	ON	**ON**	**Low**	**Low**	ON	ON
All indications remain normal until touchdown at CPT										
75792	**Ground**	*14:43:13*	No Warn	No Warn	ON	ON	Low	Low	ON	ON

Appendix 4: Cabin altitude warning procedure from QRH

CABIN ALTITUDE WARNING or Rapid Depressurization

CABIN ALTITUDE **(If installed and operative)**

Condition: One or more of these occur:
- A cabin altitude exceedance
- In flight, the intermittent cabin altitude/configuration warning horn sounds or a CABIN ALTITUDE light (if installed and operative) illuminates.

1 Don oxygen masks and set regulators to 100%.

2 Establish crew communications.

3 Pressurization mode selector . . . . . MAN

4 Outflow VALVE switch . . . . . Hold in CLOSE until the outflow VALVE indication shows fully closed

5 **If** cabin altitude is **uncontrollable**:

Passenger signs . . . . . ON

PASS OXYGEN switch . . . . . ON

►►Go to the Emergency Descent checklist on page 0.1

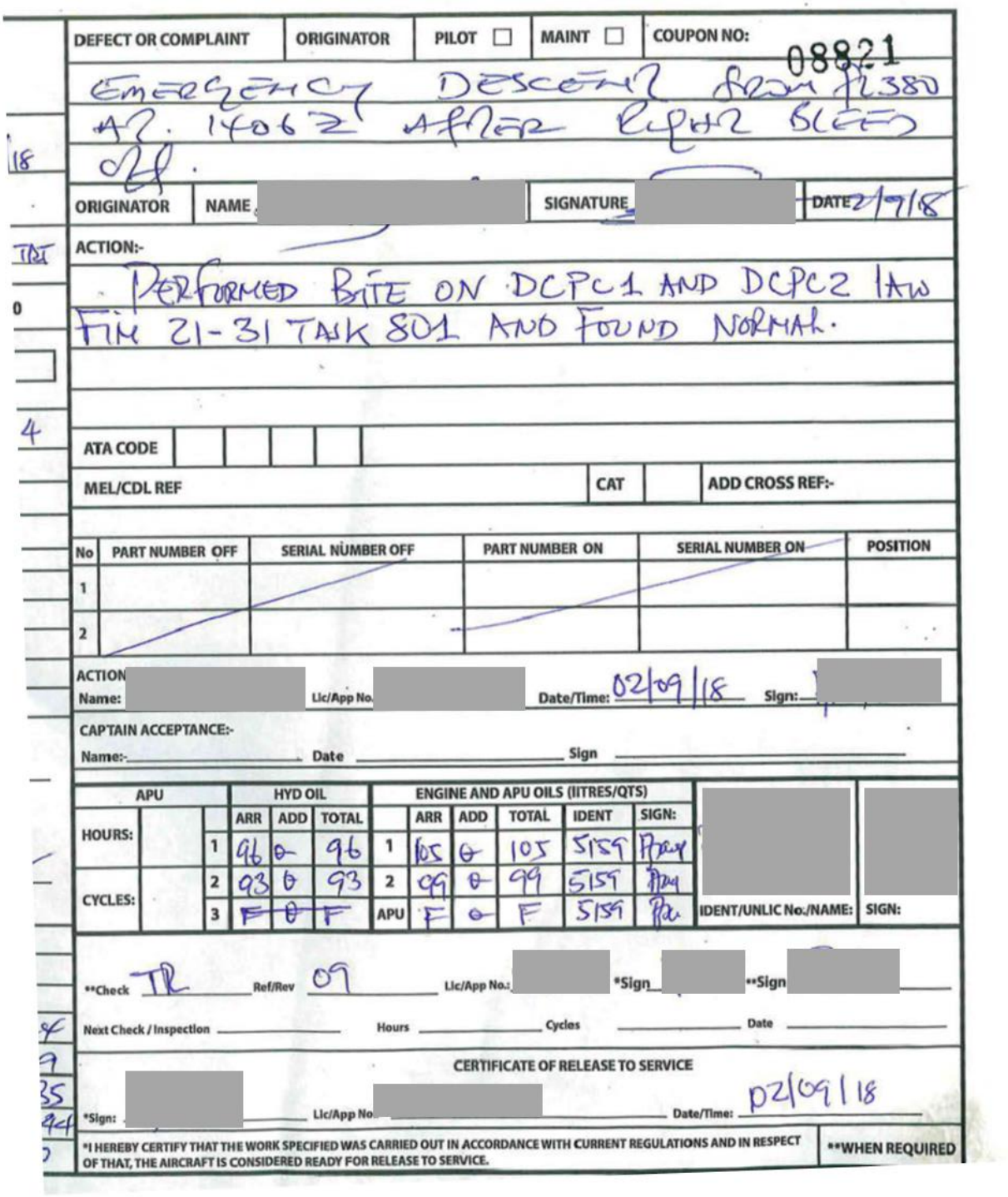
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Appendix 5: Text from occurrence report, submitted by Captain

Subject: technical fault / delay

WB 110 delayed 1.40 minutes due to incoming fault on the aircraft. Though it was a simple fault, about one hour was wasted with back and forth between the engineers. Eng # 2 was operated normally to Harare and on to Cape Town, however at around 13.50 we got a fault at 38.000 ft. The normal checklist was carried out but 15 minutes later we got a cabin altitude warning and an emergency descent was initiated to a safe level as per checklist. The flight proceeded to Cape Town to landing.
We had a right bleed trip-off at 38.000 ft. Checklist was carried out, however, about 15 min. later at time 14:06Z we got a cabin altitude warning. Emergency descent performed as per checklist. Aircraft landed Cape Town safely. Please check history of this technical re-occurrence.

Appendix 6: ATL coupon 08821 with 'release to service' signed at CPT



DEFECT OR COMPLAINT | ORIGINATOR | PILOT ☐ | MAINT ☐ | COUPON NO: 08821

EMERGENCY DESCENT FROM FL380 AT 14062 AFTER RIGHT BLEED OFF.

ORIGINATOR | NAME [redacted] | SIGNATURE [redacted] | DATE 2/9/18

ACTION:-

PERFORMED BITE ON DCPC1 AND DCPC2 IAW FIM 21-31 TASK 801 AND FOUND NORMAL.

ATA CODE

MEL/CDL REF | CAT | ADD CROSS REF:-

No	PART NUMBER OFF	SERIAL NUMBER OFF	PART NUMBER ON	SERIAL NUMBER ON	POSITION
1					
2					

ACTION Name: [redacted] Lic/App No. [redacted] Date/Time: 02/09/18 Sign: [redacted]

CAPTAIN ACCEPTANCE:- Name:- Date Sign

		APU			HYD OIL				ENGINE AND APU OILS (LITRES/QTS)					
					ARR	ADD	TOTAL		ARR	ADD	TOTAL	IDENT	SIGN:	
HOURS:			1		96	0	96	1	105	0	105	5159	[redacted]	[redacted]
CYCLES:			2		93	0	93	2	99	0	99	5159	[redacted]	IDENT/UNLIC No./NAME: SIGN:
			3		F	0	F	APU	F	0	F	5159	[redacted]	

**Check TR Ref/Rev 09 Lic/App No.: [redacted] *Sign [redacted] **Sign [redacted]

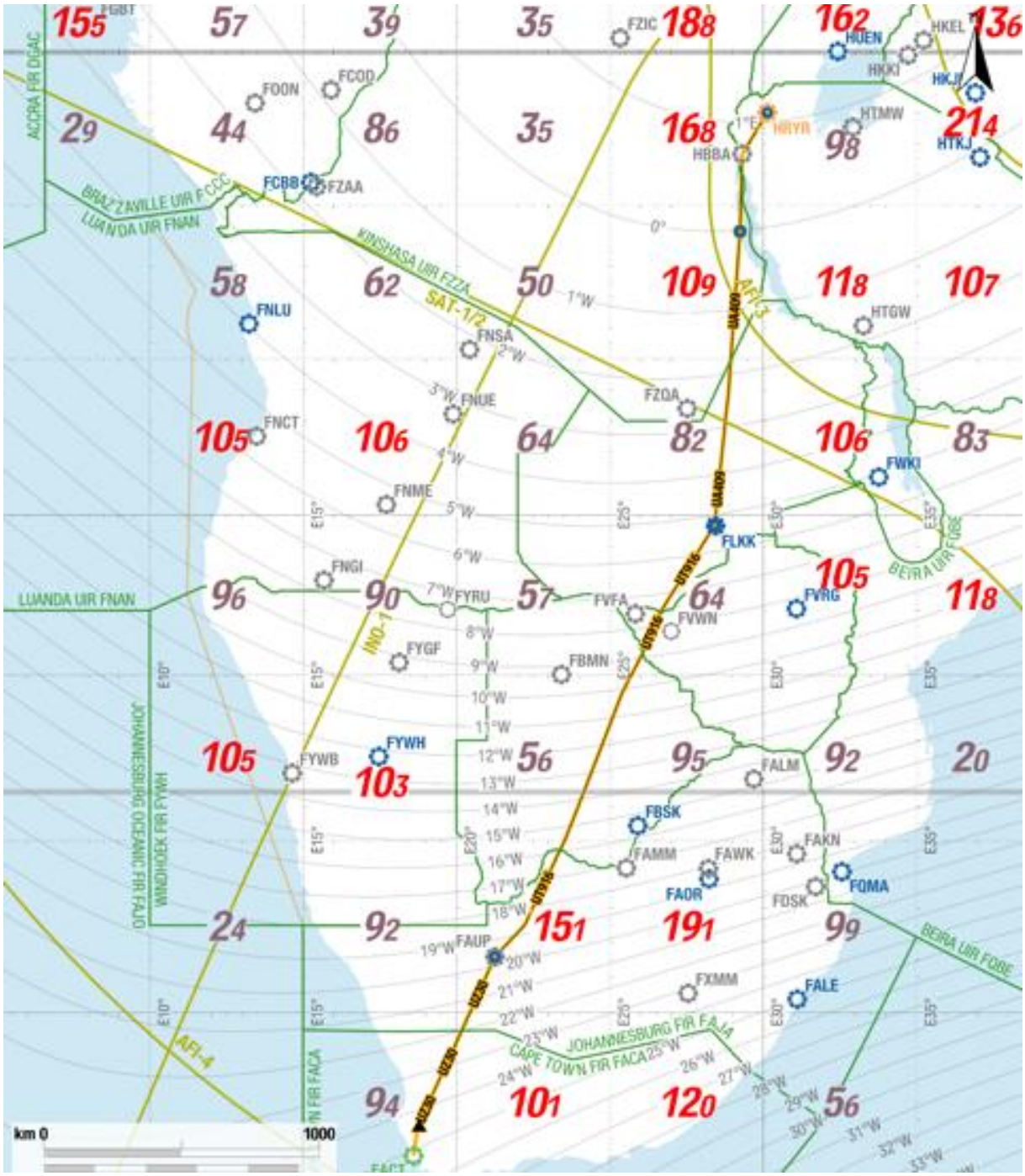
Next Check / Inspection Hours Cycles Date

CERTIFICATE OF RELEASE TO SERVICE

*Sign: [redacted] Lic/App No. [redacted] Date/Time: 02/09/18

*I HEREBY CERTIFY THAT THE WORK SPECIFIED WAS CARRIED OUT IN ACCORDANCE WITH CURRENT REGULATIONS AND IN RESPECT OF THAT, THE AIRCRAFT IS CONSIDERED READY FOR RELEASE TO SERVICE. **WHEN REQUIRED

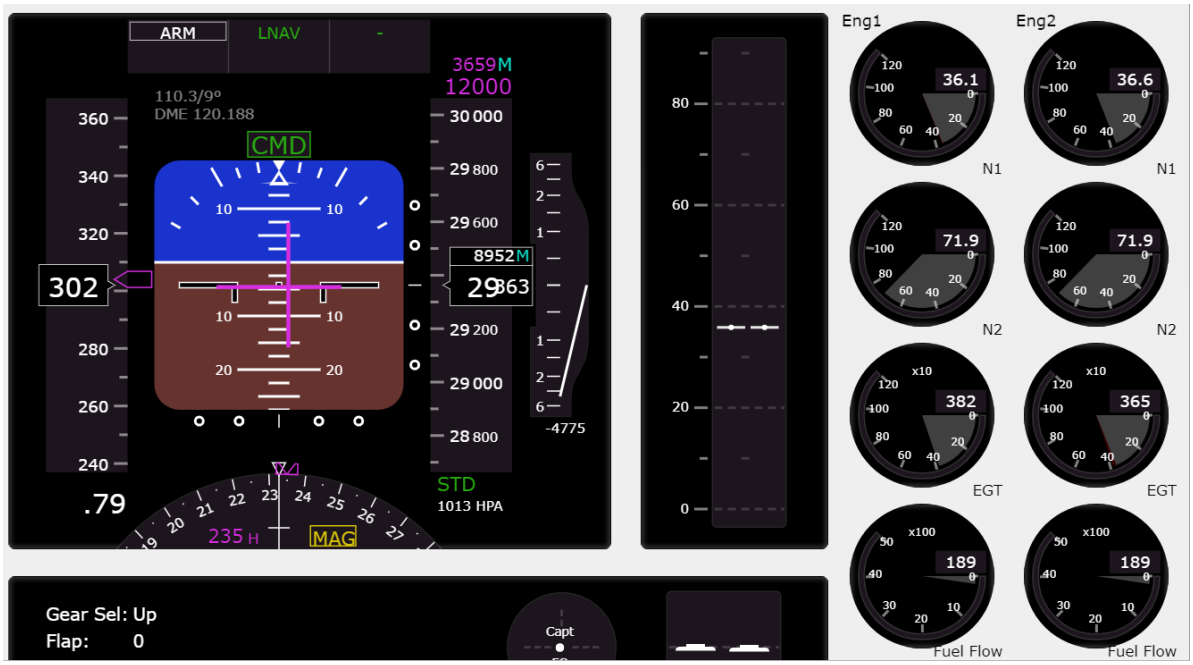
Appendix 7: minimum safe altitudes on the route KGL-HRE-CPT



Note 1: all figures are expressed in hundreds of feet. Thus **151** stands for 15.100 ft.

Note 2: numbers in red indicate a minimum safe altitude in excess 10.000 ft.

Appendix 8: Screen print of flight instruments during emergency descent



Note: the screen print depicts the situation at time 14:02:17.

From the Primary Flight Display (PFD) indications it can be derived that the aircraft at that point of time was descending with a vertical speed of 4775 ft/min, passing through an altitude of 29.363 ft with an Indicated Airspeed of 302 kts.