AIRCRAFT ACCIDENT REPORT

ASSOC/2013/10/03/F

Accident Investigation Bureau

Report on the Accident involving Associated Airlines Limited Embraer 120 ER aircraft with registration 5N-BJY, which occurred at Murtala Muhammed Airport, Lagos on 3rd October, 2013.

This report was produced by the Accident Investigation Bureau (AIB), Murtala Muhammed Airport, Ikeja, Lagos.

The report is based upon the investigation carried out by Accident Investigation Bureau, in accordance with Annex 13 to the Convention on International Civil Aviation, Nigerian Civil Aviation Act 2006, and Civil Aviation (Investigation of Air Accidents and Incidents) Regulations.

In accordance with Annex 13 to the Convention on International Civil Aviation, it is not the purpose of aircraft accident/serious incident investigations to apportion blame or liability.

Readers are advised that Accident Investigation Bureau investigates for the sole purpose of enhancing aviation safety. Consequently, Accident Investigation Bureau reports are confined to matters of safety significance and should not be used for any other purpose.

As the Bureau believes that safety information is of great value if it is passed on for the use of others, readers are encouraged to copy or reprint for further distribution, acknowledging the Accident Investigation Bureau as the source.

Recommendations in this report are addressed to the Regulatory Authority of the State (NCAA). It is for this authority to ensure enforcement.

Printed in Nigeria for the Accident Investigation Bureau (AIB)

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GLOSSARY OF ABBREVIATIONS USED IN THIS REPORT

AFM	Aircraft Flight Manual
AGL	Above ground level
AIB	Accident Investigation Bureau (The Bureau)
ATC	Air Traffic Controller
ATPL	Air Transport Pilot Licence
C of A	Certificate of Airworthiness
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
DME	Distance Measuring Equipment
DNA	Deoxyribonucleic Acid
EEC	Engine Electronic Computer
ESN	Engine Serial Number
FAA	Federal Aviation Administration
FAAN	Federal Airport Authority of Nigeria
FDR	Flight Data Recorder
FH	Flight Hour
FO	First Officer
FRSC	Federal Road Safety Corps
FSC	Fuel System Components

IFR	Instrument Flight Rules
ILS	Instrument Landing System
LDP	Landing Decision Point
LOS	Lagos
MRO	Maintenance Repair Overhaul
NAMA	Nigeria Airspace Management Agency
NCAA	Nigerian Civil Aviation Authority
NEMA	National Emergency Management Agency
NDB	Non-Directional Beacon
NTSB	National Transportation Safety Board
PF	Pilot Flying
PIC	Pilot in Command
PM	Pilot Monitoring
QNH	Airfield Pressure corrected for sea level
SOP	Standard Operating Procedure
TSN/CSN	Time Since New/Cycles Since New
TSO/CSO	Time Since Overhaul/Cycles Since Overhaul
V_1	The speed at which an aborted take-off is no longer permissible.
V_r	The speed at which the aircraft is rotated.
VHF	Very High Frequency
V_{mca}	Airborne Minimum Control Speed
VMC	Visual Meteorological Condition

VOR	Very High Frequency Omni-directional Radio Range
VSI	Vertical Speed Indicator
V_{yse}	Inoperative Rate of Climb Speed
Wx	Weather

Aircraft Accident Report No:	ASSOC/2013/10/03/F
Registered Owner and Operator:	Associated Aviation Limited
Aircraft Type and Model:	EMB 120 ER
Manufacturer:	Embraer S. A.
Year of Manufacture:	2003
Serial Number:	4078
Registration Number:	5N-BJY
Location:	Murtala Muhammed Airport, Lagos
	N 06^0 33.5' E 003^0 19.5' Elev. 55ft
Date and Time:	3rd October 2013 at about 0930hrs

All times in this report are local times (equivalent to UTC+1) unless otherwise stated.

SYNOPSIS

The Accident Investigation Bureau was notified of the accident through a phone call from NCAA, and investigators were dispatched to the site the same day. All other relevant authorities were notified.

On 3rd October 2013, SCD361 an EMB 120ER, registration 5N-BJY, a charter flight, scheduled to depart Lagos to Akure on an Instrument Flight Rules (IFR). The Captain was the Pilot Flying (PF) and the First Officer was the Pilot Monitoring (PM). The aircraft departed with No. 1 Engine torque indicator stuck at 76%. A crew-derived non-standard procedure was used to set the No. 1 Engine take-off power, as the torque indicator is the primary gauge for setting power.

After take-off power was set, a take-off flap configuration aural warning came on indicating that the flap position did not agree with the selection. This was followed by auto-feather aural warning. The No. 2 Propeller RPM was low. The PM was concerned that in addition to the warnings the aircraft was slow and advised the PF to abort the take-off. The aircraft got airborne, climbed to 118ft AGL, stalled and crashed into the Joint Users Hydrant Installation (JUHI), close to the airport, with the landing gears in the DOWN position. There was post impact fire, 16 fatalities and 4 serious injuries.

The investigation identified the following causal and contributory factors:

Causal Factor

i. The decision of the crew to continue the take-off despite the abnormal No. 2 Propeller rpm indication.

ii. Low altitude stall as a result of low thrust at start of roll for take-off from No. 2 Engine caused by an undetermined malfunction of the propeller control unit.

Contributory Factors

i. The aircraft was rotated before attaining V_1.
ii. The decision to continue the take-off with flap configuration warning and auto-feather warning at low speed.
iii. Poor professional conduct of the flight crew.
iv. Inadequate application of Crew Resource Management (CRM) principles.
v. Poor company culture.
vi. Inadequate regulatory oversight.

Four Safety Recommendations were made.

1.0 FACTUAL INFORMATION

1.1 History of the Flight

At 0902hrs the Pilot Monitoring (PM) obtained weather information from the Automatic Terminal Information System (ATIS); Lagos Terminal Information, "Hotel", Time 1000hrs, departure runway 18R, landing runway 18L, Wind 230/04, Visibility 10km, Broken 1100ft, Temperature/dew point 27/24^0 C, QNH 1014, Trend no significant change.

At 0903hrs the PM established radio communication with Lagos Ground Control on 121.9MHz and requested for engine start, destination Akure, flight level 190, registration 5N-BJY, with five hours' endurance and 20 persons on board including seven crew. At 0907hrs, start-up was granted, and the crew was requested to continue with the Tower.

No. 2 Engine was started first, followed by No. 1 Engine. At this point, the crew observed that the No. 1 engine torque indicator was stuck at 76% which prompted the PM to conduct an Electronic Engine Controls (EEC) test; however, the indicator remained at 76%. The PM invited the Engineer who was a crew member, into the cockpit to ascertain the job done on the EEC. The job done could not be determined as the engineer reported he was not part of the team that worked on the aircraft. The Engineer then requested that the PM test the EEC, but the PM responded that this had already been done several times previously. Nonetheless, the PM repeated the EEC test.

At 0920hrs the PM requested taxi clearance from the Tower. Tower cleared SCD361 taxi holding point runway 18L. During the taxi to holding point of runway 18L, the crew continued with further discussions on the state of the aircraft without briefing or referring to any document. Considering that the No. 1 torque indicator remained stuck at 76%, the crew decided to set power using T6.

At 0926hrs SCD361 was cleared to Akure on A609, climb Flight Level 190, squawk[1] 0504 and to line-up and wait. SCD361 acknowledged. The flight crew agreed to perform a flapless take-off "again", if the flap configuration warning comes on. At 0928hrs Control Tower re-cleared SCD361 to route via R778, Flight Level 190. The crew carried out "Cleared into position" checklist; external light-AS REQUIRED, pitot static- IS ON, air conditioning-AIRCONDITIONING, transponder-TRANSPONDER, multiple alarm panel-CHECKED, condition levers-TO GO.

At about 0929hrs, SCD361 was cleared for take-off on runway 18L, wind calm and to maintain runway heading.

The PM set power to commence the take-off roll and almost immediately there was an aural warning which consisted of three chimes followed by "Take-off Flaps". The aural warning changed after a few seconds to "Take-off Flaps…. Auto Feather". The PM mentioned that the aircraft was moving slowly, called "airspeed alive", "don't push it, it's hundred" as the aural warning continued until a few seconds before impact.

The PM called "80kts". The PF responded with "Roger". Thereafter, the PM observed, stating that, "we are not getting it" and asked if the take-off should be aborted. However, the PF answered "No, let's continue".

[1] Squawk – is a secondary surveillance radar (SSR) code used for identifying aircraft on the Radar Screen.

There were no other Standard Call-Outs by the PM. The aircraft rotated at about 95 knots after an extended take off roll close to the end of the runway. After lift-off, the PM cautioned "Gently", called out "Aircraft not climbing" and almost immediately cautioned, "Don't stall". At this point, the stall warning sounded in the cockpit and PM advised PF to lower the nose a bit. A few seconds after, PF requested "full power" and PM maintained that aircraft was not climbing. The aircraft attained maximum altitude of 118 feet, drifted to the right and impacted the ground in a nose-down attitude with a steep roll to the right.

Tower called SCD361 to confirm "Ops normal" just before impact but there was no response.

This accident occurred at about 0930hrs. Visual Meteorological Conditions (VMC) existed at the time. The impact location coordinate was N06°33.5' and E003°19.5' at an elevation of 55 feet above sea level, in daylight.

1.2 Injuries to Persons

Injuries	**Crew**	**Passengers**	**Others**
Fatal	5	11	Nil
Serious	2	2	Nil
Minor/none	Nil	Nil	Nil

1.3 Damage to Aircraft

The aircraft was destroyed by the impact and post-crash fire.

Figure 1: The Damaged Landing Gear in the extended position

Figure 2: Part of the Aircraft and the damaged wall fence

Figure 3:Aircraft rear section showing burnt areas

Figure 4: A view of the rear fuselage

Figure 5: The Aircraft wreckage

Figure 6: Damaged Propeller Blade at the Crash Scene

1.4 Other Damage

The impact sequence showed evidence of the following damage including a mango tree, other trees, a power generator house and a concrete fence belonging to Joint User Hydrant Installation (JUHI).

Figure 7: A Tree impacted by the Aircraft

Figure 8: Another Tree felled by the Impact

Figure 9: The Aircraft Engine and Generator Room destroyed by post impact fire

Figure 10: A seat destroyed and flung out of the Aircraft and the damaged JUHI fence

1.5 Personnel Information

1.5.1 Pilot (Pilot Flying)

Age:	64yrs
Gender:	Male
Nationality:	Nigerian
License No.:	ATPL 1208
Licence Validity:	22nd February 2014
Medical Validity:	4th February 2014
Simulator Validity:	1st August 2013
Instrument Rating Validity:	1st February 2014

Ratings:	C-150, PA-23, B737-200, ATR-42, Dash-7, SD360, HS 125-700, B727, EMB 120, DC-9, DHC-7
Proficiency check:	Nil in 2013
Total Flying Experience:	20068hrs
Total Time on Type:	1309hrs
Last 90 Days:	6.50hrs
Last 7 Days:	Nil
Last 24 Hours:	Nil

The PF flew last on the 31st July 2013.

The PF conducted the last proficiency check on the PM. There was no documented evidence to substantiate that the PF was an NCAA Authorized Type Rating Instructor/Examiner. No evidence was available to AIB that he fulfilled any of the required crew checks in 2013, including Crew Resource Management (CRM) training.

1.5.2 Co-Pilot (Pilot Monitoring)

Age:	49yrs
Gender:	Male
Nationality:	Nigerian
Licence No.:	ATPL 4755
Licence Validity:	3rd August 2014
Medical Validity:	2nd February 2014
Simulator Validity:	30th January 2014
Instrument Rating Validity:	1st February 2014
Ratings:	EMB 120, Beech 1900D, King-Air 200, Lear-jet 45 XR.

Last proficiency check:	31st July 2013
Total Flying Experience:	4660.04hrs
Total Time on Type:	3207.00hrs
Last 90 Days:	6.50hrs
Last 7 Days:	Nil
Last 24 Hours:	Nil

The PM's most recent flight before the accident was on 31st July 2013 and there was no documented evidence of CRM training. All other NCAA recommended trainings and mandatory checks were not performed.

1.5.3 Engineer

Age:	57yrs
Gender:	Male
Nationality:	Nigerian
License No.:	AMEL 2609
License Validity:	17th August 2014
Ratings:	Cat 'A' and 'C' EMB 120ER (PW118)

1.6 Aircraft Information

1.6.1 General Information

Type:	EMB 120 ER
Serial No.:	120174
Manufacturer:	Embraer S.A.

Year of Manufacture:	1990
Registration Number:	5N-BJY
Nationality:	Nigerian
Certificate of Airworthiness Validity:	22nd October, 2013
Name of Operator:	Associated Aviation Ltd
Airframe Time Since New (TSN):	27,362
Cycles Since New (CSN):	34,609
Type of Fuel:	Jet A1

The EMB-120ER is a twin-turboprop aircraft manufactured in Brazil and has a maximum weight of 11,900 kg. It is powered by two Pratt and Whitney Canada model PW118A gas turbine engines. Each is rated at 1,800 shaft horsepower and driven through a reduction gearbox to a four-bladed Hamilton Standard constant speed, full-feathering, reversing propeller of composite construction.

The aircraft C of A had a validity of three months effective from the 26th July, 2013 to 22nd October, 2013. See Appendix D

1.6.2 Aircraft Maintenance

There was no documented evidence of any deferred defects, outstanding Airworthiness Directives (ADs) or Service Bulletins (SBs). From records, the aircraft was airworthy when it was dispatched for the flight. From conversation on the CVR, the crew and the engineer were talking about some previous maintenance done that the investigation could not find on the aircraft technical log.

Last Minor Check was (A + 2A) check on 14th June 2013 in Lagos.

Last Major Check (1C + 2C) check on the 27th October 2010 at Execujet Mtce Pty Ltd, Entrance 1, Lanseria Airport, South Africa.

The next minor check, 3A check, would have been due at 2785hrs or 13th December 2013 and the next Major Check would have been due on 25th October 2013.

The aircraft had been on ground between 14th June 2012 and 17th July 2013. According to the aircraft Tech Log, Associated Airlines Limited was carrying out engine run and taxiing of the aircraft every month.

The following components were changed on the aircraft as documented in the Aircraft Tech Log on the 31st July, 2013 during the weekly inspection: Flap Control Unit and Multifunction Display Unit. Both were tested and found satisfactory.

The aircraft operated to Ilorin on the 22nd August, 2013 when the cargo door seal was replaced.

On the 25th August 2013 No. 1 Remotely Controlled Circuit Breaker (RCCB) was replaced to clear "No. 1 electric feathering inoperative" discovered during the weekly inspection. Also changed were No. 2 Electronic Horizontal Situation Indicator (EHSI) due to "Display Abnormal" and No. 2 oil filter bypass popped-out and was replaced.

The aircraft was used for training on the 30th August, 2013 around LOS-LOS; No. 2 fuel filter was replaced following Bye Pass Light ON.

The pre-flight maintenance inspection was carried out on 3rd October, 2013 before the accident. It was discovered after engine start that Engine No. 1 Torque Indicator was unserviceable.

The following are extracts from Embraer Operations Manual Section 6-8 (Flight Controls):

FLAP SYSTEM

SYSTEM DESCRIPTION

The airplane is equipped with three flap panels in each wing, designated as inboard, nacelle, and outboard flaps.

All flaps are actuated through hydraulic actuators, one for each panel, and their displacement is electronically controlled.

The green hydraulic system supplies the outboard pair, and blue hydraulic supplies the inboard and nacelle pair. A selector located at the aft panel commands flap setting. Mechanical detents are provided for the levers 0°, 15°, and 45° positions, with a gate stop at the 15° position.

ELECTRONIC SYSTEM CONTROL

The flaps electronic control system comprises the following main components:

- *Flap position Indication (FPI);*
- *Flap Annunciator unit (FAU).*

Once the pilot selects the desired flap position on the selector lever, the information is transmitted to the Annunciator through three independent control channels. The flap position setting is transmitted to the flap control unit (FCU) that commands the proper actuators. The Annunciator unit display information about the system's operation by means of light bars, which individually display the position of each panel flap panel and the selected flap position. This unit continuously monitoring each flap panel displacement, and also may disengage the normal actuators control.

The flap position indicator is an analogue, single pointer instrument that shows the weighted flap displacement average.

NOTE:

- *If during takeoff the flap position is not consistent with the approved takeoff setting, the TAKEOFF FLAPS voice message will sound.*
- *For airplanes equipped with alphanumeric display on the annunciator panel, in case of flap position indicator failure, the alphanumeric display will present the INVALID ANLG IND message.*
- *On post-mod. SB 120-31-0009 airframes S/N 120.058, 120.064, 120,.066 and on are equipped with the Flap Warning Indication Panel (FWIP), installed on the overhead panel, just below the Flap Annunciator panel.*
- *In this case, the faults are also indicated by the ASYMMETRY, DISAGREEMENT or CONTROL FAULTS lights*

SYSTEM FAULTS

CONTROL FAULT

The control fault is characterized by a failure in any of the Flap Control Unit channels of the Flap Annunciation Unit or in the Flap Selector Lever.

Once a control fault occurs, disagreement output is inhibited to prevent one failure triggering two alarms simultaneously.

Indication:

- FLAP and ADVANCED SWS lights flashing on the Multiple Alarm Panel;

- CONTROL FAULT light illuminated on the Flap Warning Indication Panel;

- CONTROL FAULT indication on the Annunciation Panel's alphanumeric display

(if applicable);

- Lights bar of the respective pair flashing on the Annunciation Panel.

When a control fault is detected in any control channels, the respective pair is disengaged. In case of detecting a control fault in the Annunciator Panel or in the Flap Selector Lever, all three pairs will be disengaged.

NOTE: *In the case of flap control fault, the shaker will actuate as if the flaps were set at 45^0 and the pusher will actuate as if were set at 0^0.*

DISAGREEMENT

A disagreement is characterized when the difference between two or more pairs is more than 7 degrees.

Indication:

- *FLAP and ADVANCED SWS lights flashing on the Multiple Alarm Panel;*
- *DISAGREEMENT light illuminated on the Flap Warning Indication Panel;*
- *DISAGREEMENT indication on the Annunciator Panel's alphanumeric display (if applicable).*
- *All channels lights bars flashing on the Annunciator Panel.*

NOTE: *In the event of a disagreement failure on aircraft equipped with an alphanumeric display on the annunciator panel, the message DON'T OVRD will also be shown on the alphanumeric display, associated with a flap pair in disagreement. Should more than one message be requires to be shown, they are alternately indicated on the alphanumeric display.*

Asymmetry

An asymmetry condition occurs when two flap panel in the same pair differ in position by more than 7^0 degrees. Once the asymmetry fault has been detected, the system will disengage the affected pair and the disagreement output is inhibited to prevent one failure from triggering two alarms simultaneously.

Indication:

- *FLAP light flashing on the multiple alarm panel.*
- *Light illuminated on the Flap warning indication panel.*
- *ASYMMETRY indication on the Annunciator panel's alphanumeric display (if applicable).*
- *Affected channel light bar flashing*

NOTE: *If necessary, the Pilot should operate (sic) the override switch in order to eliminate the asymmetrical condition. The operation consists in driving the good flap panel toward the malfunctioning flap panel*

In this case, the faults are also indicated by the ASYMMETRY, DISAGREEMENT or CONTROL FAULT lights.

1.6.3 Powerplant

No. 1

Manufacturer:	Pratt and Whitney
Year of Manufacture:	2009
Hours:	818.5hrs
Model:	PW118A
Cycles:	Not Available
Serial Number:	TM–AA0045
Last Check:	C1 inspection 27th October, 2010

No. 2

Manufacturer:	Pratt and Whitney
Year of Manufacture:	1989
Hours:	25134.5hrs
Model:	PW118A
Cycles:	Not Available
Serial Number:	115388
Last Check:	C1 inspection 27th October, 2010

The following are extracts from the Aircraft Ops Manual Section 6.3.3.:

GENERAL DESCRIPTION

The engine comprises two independent modules, the TURBOMACHINERY (TMM) and the reduction gearbox. The turbo machinery comprises a twin-spool compressor, low Pressure Compressor (LP) and High Pressure Compressor (HP), a low pressure turbine, a high pressure turbine and a two-stage power turbine. The turbo *machinery produces power through compression, combustion, and turbine rotation. The reduction gearbox reduces the input speed from the torque shaft of the turbine machinery (20000 RPM) to the propeller shaft (1300 RPM).*

The low-pressure and high-pressure centrifugal compressor provides two stage of compression. Compressed air enters the reverse-flow combustion chamber ignite the fuel-and-air mixture. The hot expanding combustion gases are directed towards the turbines.

The engine is a "free turbine" design featuring three independent shafts, each rotation at an individual speed. Each vane and corresponding turbine converts energy from the combustion gas into a mechanical rotational force. The high-pressure turbine turns the high-pressure impeller and accessory gearbox. The low-pressure turbine turns the low-pressure compressor. The two-stage power turbines provide rotational force for the reduction gearbox. During the start sequence, the high-pressure compressor is running, the HP compressor rotates accessories such as the fuel and oil pumps mounted on the accessory gearbox.

A hydro mechanical fuel control unit (HMU) regulates fuel flows to the fuel nozzles in response to power requirements and flight condition. The HMU can be operated in EEC mode (electronic engine control) or manual mode (Manual pilot input).

The engines also provide bleed air for the pressurization and de-ice system.

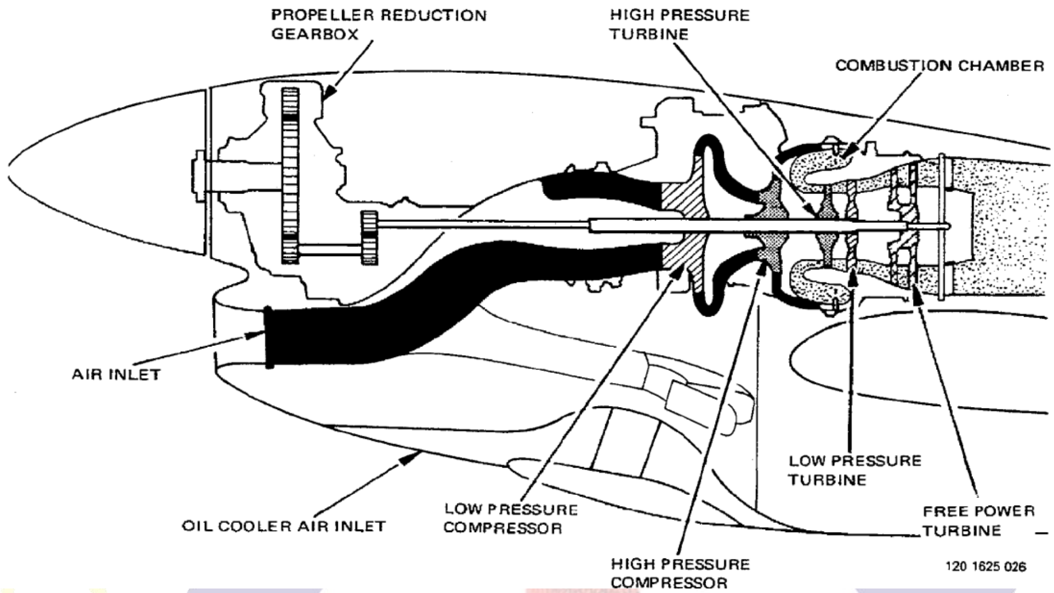


Figure 11: Schematic Diagram of Engine Computer System

In the event of EEC reversion to the manual mode the MANUAL light in the EEC control panel and the EEC red light in the glare shield panel will illuminate.

When the EEC is turned ON, the initialization procedure will be accomplished, and will take a short period of time. If the airplane altitude is above 14000ft, during this short period of time the engine fuel flow will be initially reduced and then increased in order to reach the programmed value within the EEC schedule.

This fact may cause undesirable engine parameters fluctuation.

After the initialization period, the EEC will normally assume the engine fuel control.

In order to prevent these fluctuations, proceed as follows:

- *Perform the EEC transition from manual mode to normal mode during climb at lowest convenient altitude.*
- *Reduce power lever to a lower power setting before switching the EEC on.*
- *After the stabilisation of engine parameters, advance the power lever to obtain the desired power setting.*

***NOTE**: This procedure shall be performed separately on each engine, if both EECs require reset/transition.*

1.6.4 Electronic Engine Control (EEC)

The following are extracts from the Aircraft Ops Manual Section 6.3.3.:

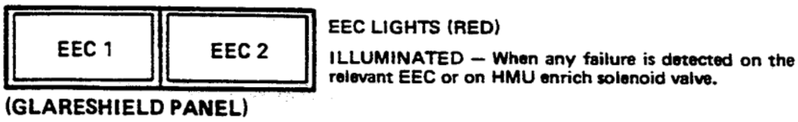
The EEC is a microprocessor-based engine control which executes a program defined by the programmable read-only memory (PROM) and it is mounted on the engine air-inlet front case, at nine o'clock position

The EEC has function of controlling the engine fuel flow within the EEC schedule upper and lower limits established in the Hydro-mechanical metering unit (HMU). EEC may be either on or off to start the engine. EEC on starting will be characterize by two temperature peaks, while the EEC off is characterized by slower starting and only one temperature peak.

It is important to observe that below 25% N_H, only the HMU is responsible for controlling the fuel flow above 25% N_H, the EEC, when on begins to govern the minimum N_H or V_p speed fuel flow to the engine.

In the event of EEC electrical power interruption or a particular sensor failure and software malfunction, the control system will revert to the HMU schedule defines as manual control mode.

Electronic Engine Control Reset/Transition



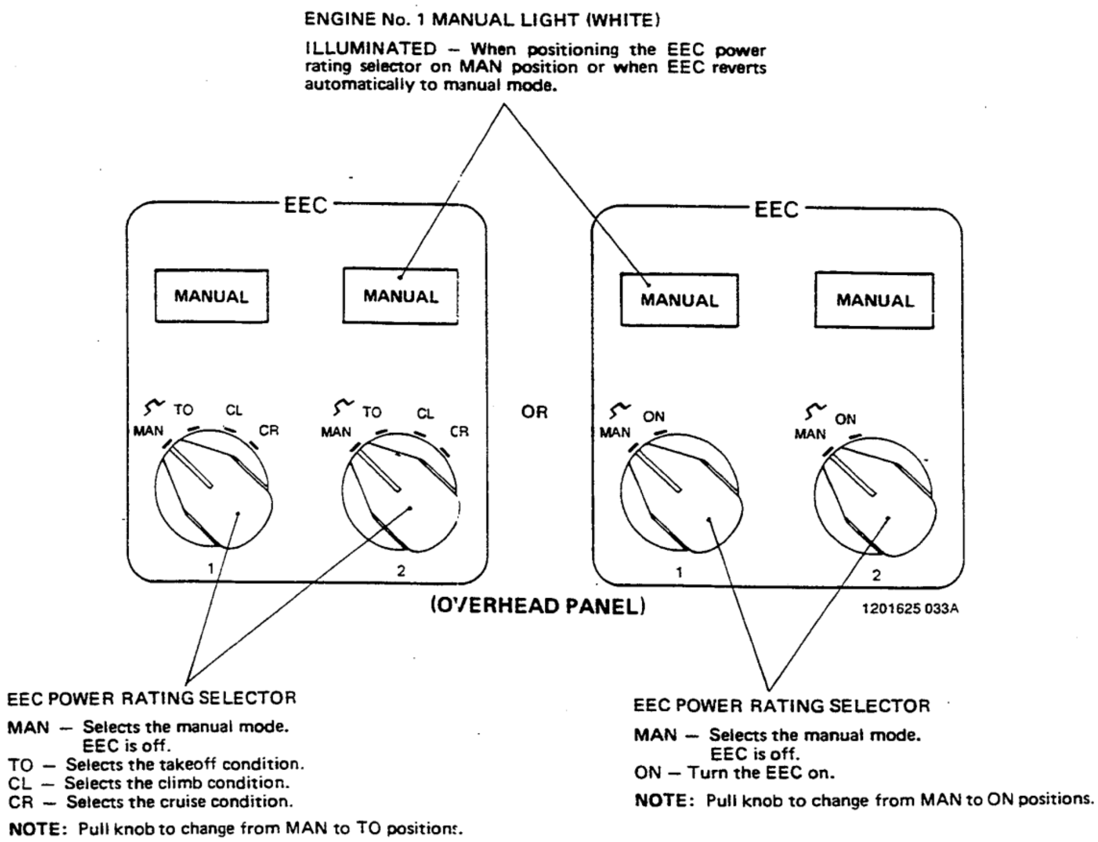


Figure 12: Electronic Engine Control Reset

1.6.5 Propeller Information

Model Number:	14 RF-9
Manufacturer:	Hamilton Sundstrand

No. 1

Serial Number:	881208
Total Time Since New:	Not Available
Total Time Since Overhaul:	7994hrs

No. 2

Serial Number:	891141
Total Time Since New:	Not Available
Total Time Since Overhaul:	4199.30hrs

PROPELLER

GENERAL DESCRIPTION

The EMB-120 BRASILIA is equipped with two Hamilton standard, model 14 RF-19 propellers. The propellers are mechanically actuated by the power turbines of the relevant engines, at reduction rate of 15:1 (20000 RPM of the power turbine corresponds to approximately 1300 RPM of propeller).

The pitch being hydraulically controlled by the propeller control unit (PCU).

The oil used to control the propeller comes from engine lubrication system and it is supplied through oil auxiliary tank, which feeds both the mechanical pump and the electrical auxiliary feathering pump. In case of engine lubrication system failure or with engine inoperative. The auxiliary tank always keeps a minimum oil level, capable of ensuring propeller full feathering through the electrical auxiliary feathering pump.

In normal operating conditions, only the mechanical pump will be operative.

Propeller maximum governed speed varies from 1300 to 1309RPM (100% - 100.7% NP), and pitch adjustment range varies from + 79.2° (feather) down to – 15.0° (Reverse), measured in blade station N° 42.

EMB- 120 propeller system incorporates the following components in each propeller assembly:

- *01 Hamilton standard, four-blade, model 14 FF-9, clockwise rotation (as viewed from behind), variable pitch, tractor, reversible and feathering propeller.*
- *01 mechanical pump actuated by the power turbine shaft through the reduction gearbox accessory section, which is responsible for high pressure oil supply (780 ± 30 PSI) to the PUC, over speed governed and propeller servomechanism.*
- *01 electrical auxiliary feathering pump which will supply high pressure oil (820 ± 30 PSI) for propeller feathering.*

  The electrical pump can be activated by one of the following means: the electrical or the automatic feathering system, the fire extinguishing system handle or the pump test button.
- *01 propeller control unit (PCU) which will control propeller pitch and speed*
- *01 over speed governor which provides propeller maximum speed control, in case of PCU failure.*
- *01 flight low pitch secondary backstop system.*

Additionally, the EMB-120 propeller system incorporates an automatic feathering system and a synchronization system which actuates simultaneously on both propeller assemblies.

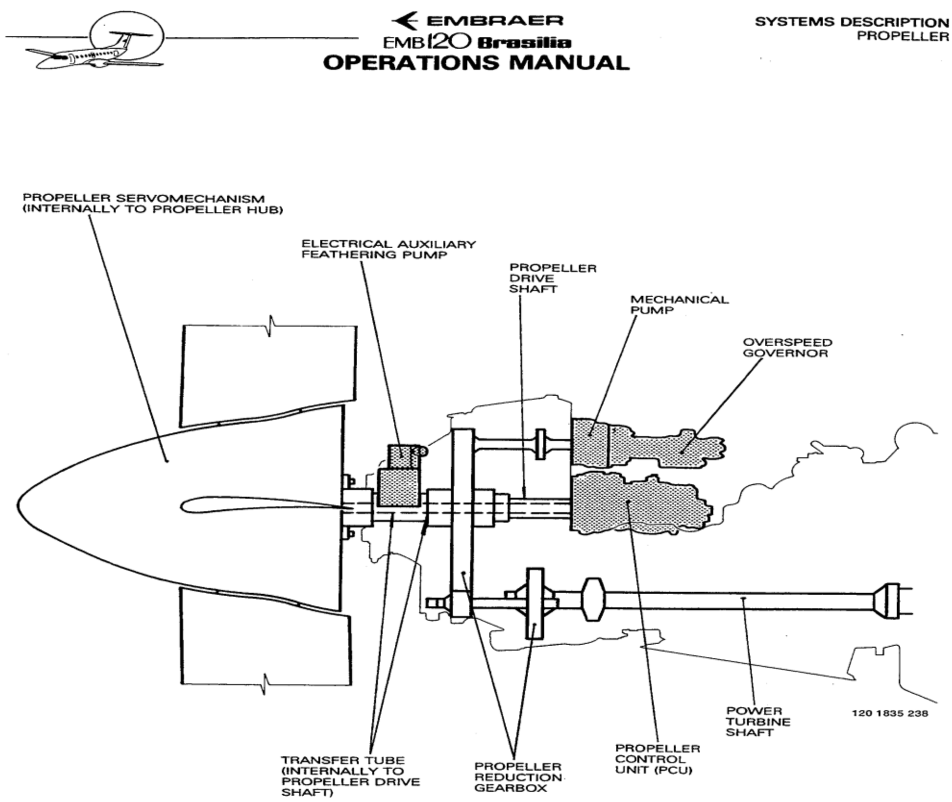


Figure 13: Propeller Control System Components

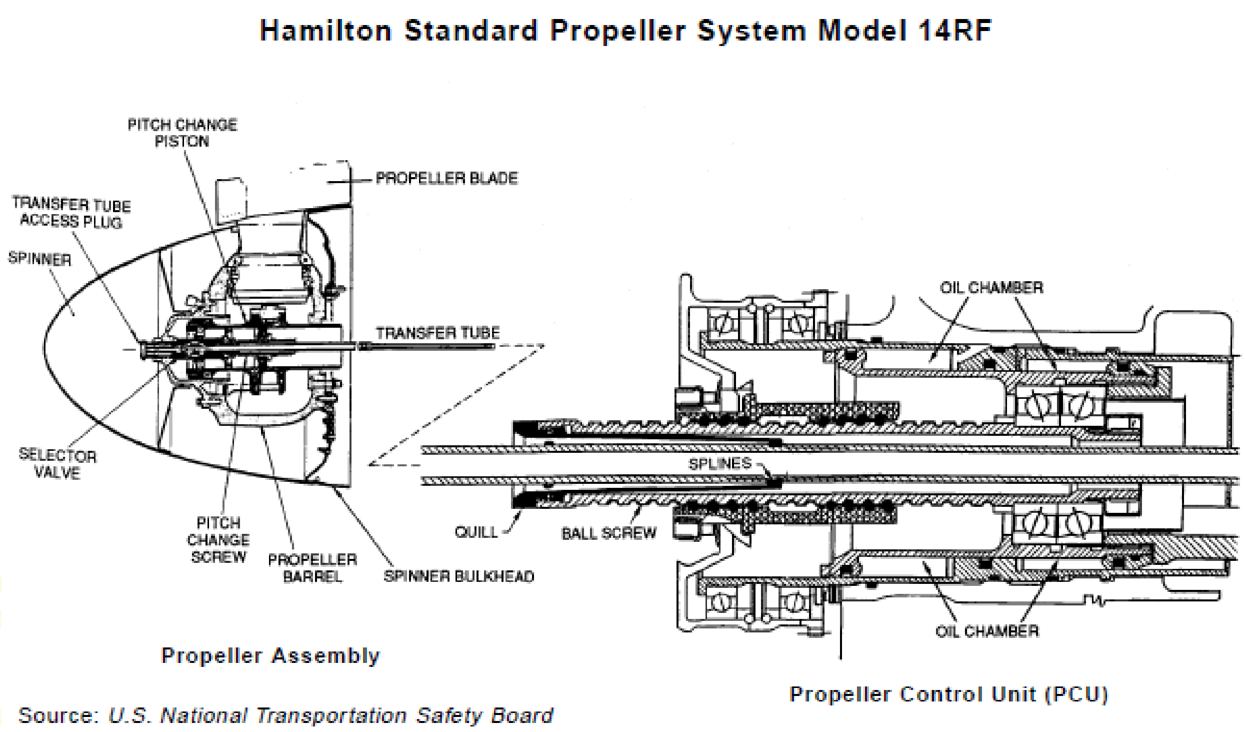


Figure 14: Standard Propeller System

1.6.5.1 Automatic Feathering System

The auto-feathering system will automatically feather the propeller whose relevant engine undergoes a power loss during take-off or go-around. The system acts upon the feathering solenoid valve and upon the auxiliary electrical feathering pump, by means of the electrical feathering system electrical unit.

The system is composed of:

- SCU's (Torque signal conditioning units) of both engines.

- Two-position (ON/OFF) AUTOFEATHER switch located on the overhead panel.

- Two micro switches, located within the control pedestal which are energized whenever the power levers are positioned above 62^0 PLA (Typical take off power setting).

- Two test buttons, one for each propeller, which enables the system to be tested.

Each test button, when pressed, simulates both an engine high torque condition and the power levers positioning at take-off.

-A green indicating light bearing the inscription ARMED, which indicates whether the system is armed or not.

In this way, the system is armed when the following conditions are met simultaneously:

-AUTO FEATHER switch at ON.

- Torque of both engines above 62.0±1.4%

- Both power levers positioned above 62^0 PLA.

Under these conditions the system is ready to operate, as the ARMED indicating light illuminates. A synthesized voice (TAKE OFF –AUTOFEATHER) will warn the crew, 8 seconds after the power levers are positioned above 62^0 PLA, if the auto-feathering system is not armed during take-off. The automatic feathering system is activated whenever torque of one of the engines drops below 23.6±2.5%.

In this case, the ARMED indicating light extinguishes and the relevant propeller is feathered. Simultaneously, the automatic feathering control circuit is interrupted for the opposite propeller, thus preventing it from feathering, in the event its engine undergoes a power loss also.

*(*When the auto feather system was unintentionally not armed for take-off, a three-chime aural alert sounded and a voice message warning 'Take-off auto feather' activated 8 seconds after the power levers were advanced).

NOTE: After the automatic feathering system actuation, propeller unfeathering will only be possible with the AUTO FEATHER switch positioned to OFF.

1.6.5.2 Engine and Propeller Controls

The engine and propeller controls in the EMB-120 are mounted on a central pedestal between the left (PIC) and right (co-pilot) seats.

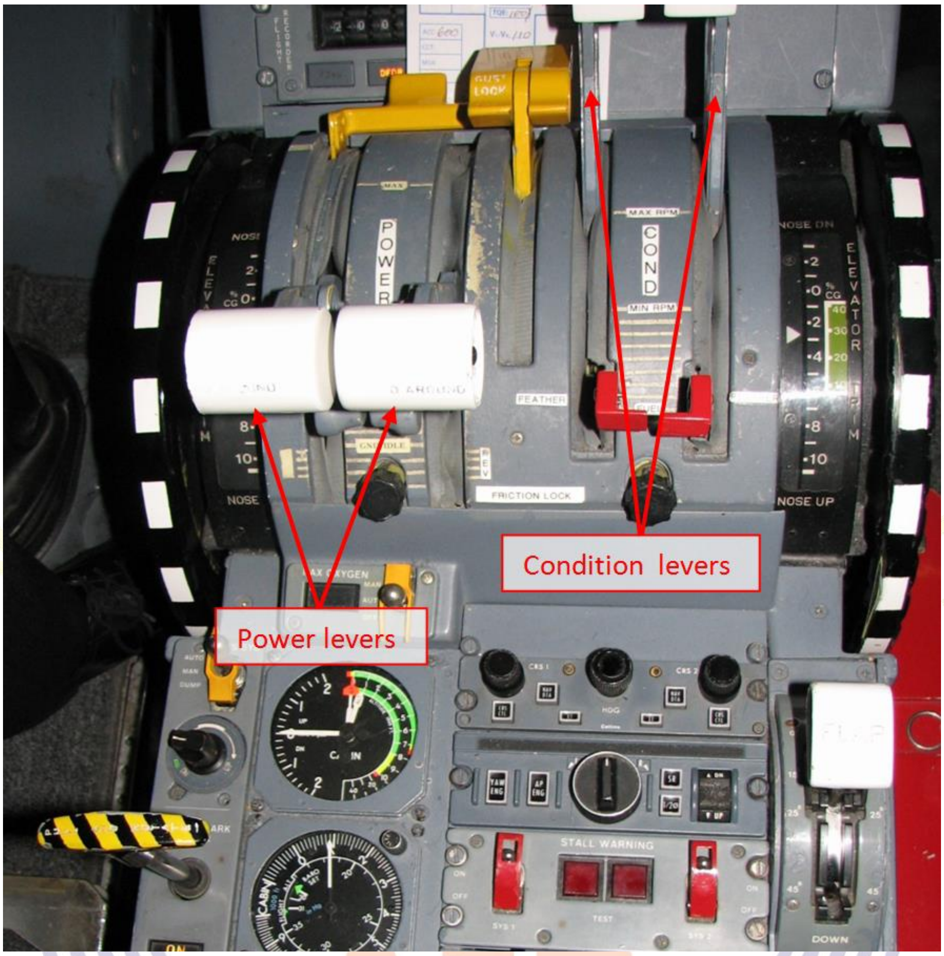


Figure 15: Power Quadrant with the Power levers (left) at flight idle and the Condition levers (right) at maximum RPM

1.6.5.3 Power Levers

Two power levers, one for each engine, are located on the left of the quadrant and control the fuel fed to the engines through a hydro-mechanical unit (HMU) in conjunction with each engine's electronic engine control (EEC). A warning lamp on the centrally-mounted multiple alarm panel (MAP) illuminated when a failure is detected in the respective EEC.

The position of the power levers is dependent on the torque required and ranged from flight idle (FLT IDLE) at the most rearward lever travel to maximum power

(MAX PWR) toward the forward limit of travel. Maximum power is partly determined by environmental conditions and the power levers are advanced until the required torque value or temperature limit is achieved on the engine gauges. The PW118A engine permits the use of 110% torque for up to 5 minutes during takeoff if required, and a maximum transient torque of 120% for 20 seconds. Torque in excess of these values are possible, although engine damage would probably result.

The power levers also control the propellers in ground or beta (control mode) in normally automatic propellers, in which a pilot exercises direct (or manual) command of the propeller pitch (blade angle) for braking and ground manoeuvring 14 range for ground operations. The beta mechanism control the propeller in an under speed condition, when the propeller governor is deactivated due to low propeller speed and the propeller blade angle is controlled directly by power lever movement. The blade pitch angle range in the beta schedule is from -11° (full reverse) through to +25°.

Condition Levers

Two condition levers on the right of the quadrant are mechanically connected to the propeller control unit (PCU) and control propeller pitch (blade angle) for constant speed operation and feathering. The levers could be set at any position between the most forward limit (maximum RPM "MAX RPM") and the most rearward limit (minimum RPM "MIN RPM"). Lifting the condition levers up and rearwards from the minimum RPM stop engages the mechanical feathering operation. For takeoff, the condition levers are set to MAX RPM and a propeller speed governor increases or decreases propeller pitch to maintain the selected propeller speed or RPM while airspeed increases.

Engine and Propeller Gauges

Gauges for engine torque in percent (% TORQUE), propeller speed in percent RPM (Np) and inter-turbine temperatures (T6) for each engine were located in the central panel, adjacent to the captain's flight instruments (Figure). Those gauges provided analogue and digital representations of the respective parameters.

Figure 16: Engine Inter-turbine Temperature (T6) (top row) and Torque (centre row) Gauges and propeller RPM (NP) Gauges (bottom row).

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III - Model EMB-120ER "BRASILIA" (Transport Category), approved 07 February 1992.

ENGINE
2 Pratt & Whitney of Canada Ltd. PW-118; or
2 Pratt & Whitney of Canada Ltd. PW-118A (See Note 6); or
2 Pratt & Whitney of Canada Ltd. PW-118B.

FUEL
Brazilian Specification CNP-08/QAV1 and QAV4.
Pratt & Whitney Specification CPW 204.
ASTM Specification D1655 - JET A, JET A-1, JET B.
MIL-T-5624 - JP-4, JP-5.
Aviation Fuel - See Flight Manual for limitations.

ENGINE LIMITS (PW-118)

Operation Condition	Operational Limits							
	NL %	SHP	Torque % (lb.ft)	T6 °C	NH %	NP %	Oil Pressure psid	Oil Temp. °C *9
Takeoff Max. Cont.	100.0	1 800	100.0 *7 (7 272)	800	100.0	100.0 *6	55 to 65	45 to 100
Ground					62.0	65.0 *10	40*3	-40 to 100 *1
Starting				850 *5 950 *2				-40
Transient	103.0 *5		120 *5 (8 726)	850 *5	102.0 *5	110.0 *5		100 to 115 *4
Max. Reverse			-	785	100.0	80.0 *8	55 to 65	45 to 100
Max. Climb Max. Cruise	100.0	1 512	84.0 (6 108)	800	100.0	100.0 *6	55 to 65	45 to 100

Obs: NL indication: a warning light illuminates when the gas generator low pressure exceeds the speed range of 25 to 100 %.

*1 A minimum oil temperature of 0°C is necessary for power above "ground idle".
*2 This value is limited to 5 sec.
*3 The normal oil pressure is 55 to 65 psid with NH rotation over 75 %. A minimum pressure of 40 psid is acceptable between 62 to 75 % of NH.
*4 Oil temperature between 100 to 115°C is an abnormal condition and is limited to 15 min.
*5 This value is limited to 20 sec.
*6 Tolerance of the maximum NP value is 100.0 to 100.7 %.
*7 Torque values up to 110.0 % are acceptable for take-off.
*8 Must remain stationary after the reverse setting.
*9 The oil temperature must be maintained above 45°C to assure engine air intake deicing and avoid ice fuel formation.
*10 During all ground operations the condition levers must be at MIN RPM position, except for takeoff and landing rolls.
During all ground operations the power levers must be at or below FLIGHT IDLE, except for short time periods (5 sec) for aircraft ground handling.
Caution: Ground operations above FLIGHT IDLE increase propeller blade stresses significantly in some adverse wind directions (for instance cross and tail winds). Operations in this RPM range should be avoided as much as possible. (See Flight Manual)

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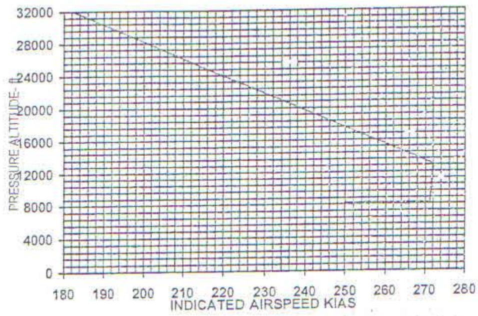
PROPELLER AND PROPELLER LIMITS

2 Hamilton Standard 14RF-9, blades RFC11N1-6A, RFC11M1-6A, RFC11E1-6A, RFC11U1-6A and RFC11AA1-6A.

Maximum speed (100.0 % NP):	1 300 rpm
Diameter:	3 200 mm
Pitch settings (at STA 1 067 mm):	79.2° to -15°
Number of blades:	4

AIRSPEED LIMITS (IAS)

Maximum operating (V_{MO}):



Maneuvering (V_A) - sea level:	370 km/h (200 kias)
Flaps extended (V_{FE})	
- 15° (takeoff):	370 km/h (200 kias)
- 25° (approach):	278 km/h (150 kias)
- 45° (landing):	250 km/h (135 kias)
L. G. operation (V_{LO}):	370 km/h (200 kias)
L. G. extended (V_{LE}):	370 km/h (200 kias)

C. G. LIMITS
(landing gear extended)

For ground conditions, landing and take-off:
- 8 453 to 8 827 mm (23.3 % to 42 % MAC) with 12 070 kg
- 8 453 to 8 827 mm (23.3 % to 42 % MAC) with 11 990 kg
- 8 107 to 8 827 mm (6 % to 42 % MAC) with 8 300 kg
- 8 107 to 8 827 mm (6 % to 42 % MAC) with 7 200 kg
- 8 107 mm (6 % MAC) with 6 500 kg

For flight conditions:
- 8 453 to 8 827 mm (23.0 % to 42.0 % MAC) with 11 990 kg
- 8 377 to 8 857 mm (19.5 % to 43.5 % MAC) with 11 500 kg
- 8 255 to 8 867 mm (13.4 % to 44 % MAC) with 10 300 kg
- 8 067 to 8 867 mm (4 % to 44 % MAC) with 8 300 kg
- 8 067 to 8 867 mm (4 % to 44 % MAC) with 7 200 kg
- 8 067 mm (4 % MAC) with 6 500 kg

Straight line variation between points given.

Moment due to landing gear retraction: -257 000 kg x mm (the aircraft CG is moved forward with retraction).

MAXIMUM WEIGHTS	Ramp:	12 070 kg
	Take-off:	11 990 kg
	Landing:	11 700 kg
	Zero fuel:	10 900 kg

MAXIMUM PASSENGERS 30

MAXIMUM BAGGAGE 550 kg (see Note 7).

MANUFACTURER SERIAL NUMBER See Note 8.

IV - Model EMB-120FC "BRASILIA" (Transport Category, Full Cargo Version), approved 01 June 2000.

ENGINE
2 Pratt & Whitney of Canada Ltd. PW-118; or
2 Pratt & Whitney of Canada Ltd. PW-118A (See Note 6); or
2 Pratt & Whitney of Canada Ltd. PW-118B.

FUEL
Brazilian Specification CNP-08/QAV1 and QAV4.
Pratt & Whitney Specification CPW 204.
ASTM Specification D1655 - JET A, JET A-1, JET B.
MIL-T-5624 - JP-4, JP-5.
Aviation Fuel - See Flight Manual for limitations.

ENGINE LIMITS (PW-118)

Operation Condition	Operational Limits							
	NL %	SHP	Torque % (lb.ft)	T6 °C	NH %	NP %	Oil Pressure psid	Oil Temp. °C *9
Takeoff Max. Cont.	100.0	1 800	100.0 *7 (7 272)	800	100.0	100.0 *6	55 to 65	45 to 100
Ground					62.0	65.0 *10	40*3	-40 to 100 *1
Starting				850 *5 950 *2				-40
Transient	103.0 *5		120 *5 (8 726)	850 *5	102.0 *5	110.0 *5		100 to 115 *4
Max. Reverse				785	100.0	80.0 *8	55 to 65	45 to 100
Max. Climb Max. Cruise	100.0	1 512	84.0 (6 108)	800	100.0	100.0 *6	55 to 65	45 to 100

Obs: NL indication: a warning light illuminates when the gas generator low pressure exceeds the speed range of 25 to 100 %.

1.6.5.5 Take-off performance

Charts in the EMB-120 aircraft flight manual (AFM) enable the determination of V1/VR (decision speed) and V2 (take-off safety speed) for different aircraft weights, configurations, environmental and runway conditions. Flying at a speed of V2 guarantees a margin of 10% above VMCA (The airborne minimum control speed) and 20% above VS, whichever is greater. Adjustable airspeed reference markers or speed bugs on the bezel of the airspeed indicator dial are set to display the reference speeds for takeoff.

1.7 Meteorological Information

The crew were provided with current weather condition by ATC and ATIS. The following weather conditions prevailed on the day of the occurrence: from 0700 to 0900 UTC:

Wind:	230/05KT
Visibility:	10km
Weather:	Nil
Cloud:	BKN 330m
Temperature/Dew pt.:	27/24
QNH:	1014
Trend:	NOSIG

1.8 Aids to Navigation

The ground-based navigation aids, on-board navigation aids, airport visual ground aids were all serviceable at the time of the accident.

1.9 Communications

There was good communication between the aircraft and Air Traffic Control (ATC). All communications between ATC and the crew were recorded by ground based automatic voice recording equipment for the duration of the accident flight. The quality of the aircraft's recorded transmissions was good. All VHF radios were serviceable.

1.10 Aerodrome Information

Murtala Muhammed International Airport, Ikeja, Lagos, has a location indicator DNMM, elevation of 135ft and a reference point of N06 34′ 38″ and E003 19′ 16″. The airport has dual bi-directional runways with a concrete/asphalt surface, designated as runways 18L/36R and 18R/36L. Both runways are equipped with ILS; ILS for runway 18L (110.3 MHz), ILS for runway 18R (108.1MHz), a VOR/DME (113.7MHz) which is aligned with runway 18L centre line and a VOR/DME (112.9MHz) aligned with runway 36L centre line. There is a locator beacon, NDB 336kHz aligned with runway 18L centre line.

The runway length of 18L/36R is 9,006ft (2745m) with blast pads of 50/65 metres and runway 18R/36L is 12,795ft (3900m) with blast pads of 120 metres on both ends. The approach lights on both runways were serviceable at the time of the accident as there was no NOTAM to indicate otherwise.

The Precision Approach Path Indicator (PAPI) was available for both runways.

1.11 Flight Recorders

The aircraft was equipped with both Cockpit Voice Recorder (CVR) and Flight Data Recorder (FDR) as required by the regulation. Both recorders were recovered from their installed positions (aft section of the airframe) and transported to Accident Investigation Bureau (AIB) facilities in Abuja for examination and data download.

The recording was good and showed no evidence of loss of quality as a result of the crash.

The FDR contained approximately 47 hours of data in solid state memory and the recorder was downloaded successfully. The FDR recorded about 50 parameters, a few of which were not properly retrieved in the download. Airspeed was one of the parameters that was not captured, though it was working in the cockpit.

The CVR was an older generation magnetic tape based device. It contained thirty-two and half minutes (321/2) of audio which included the internal conversation of the two pilots, radio calls, the overall aural environment in the cockpit area microphone, the CVR was of good quality and the download was successfully carried out.

1.11.1 Flight Data Recorder (FDR)

Part Number:	S800-2000-00
Model:	F1000
Serial Number:	01437
Manufacturer:	Fairchild
Manufactured Date:	06/1996

1.11.2 Cockpit Voice Recorder (CVR)

Part Number:	93-A100-83
Serial Number:	54937
Manufacturer:	Fairchild
Manufactured Date:	06/1989
Manufacturer Model:	A

1.11.4 FDR Download

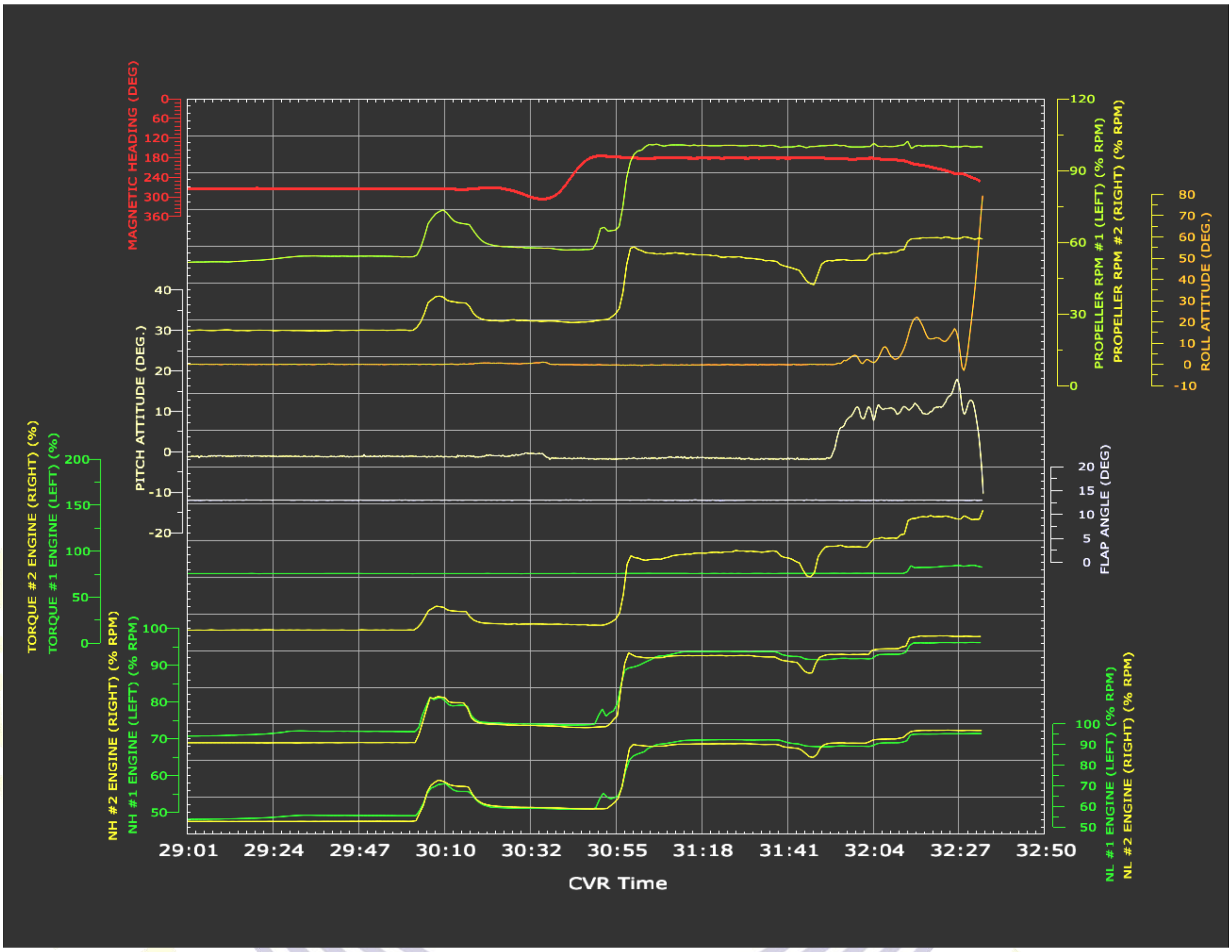


Figure 17: FDR Traces

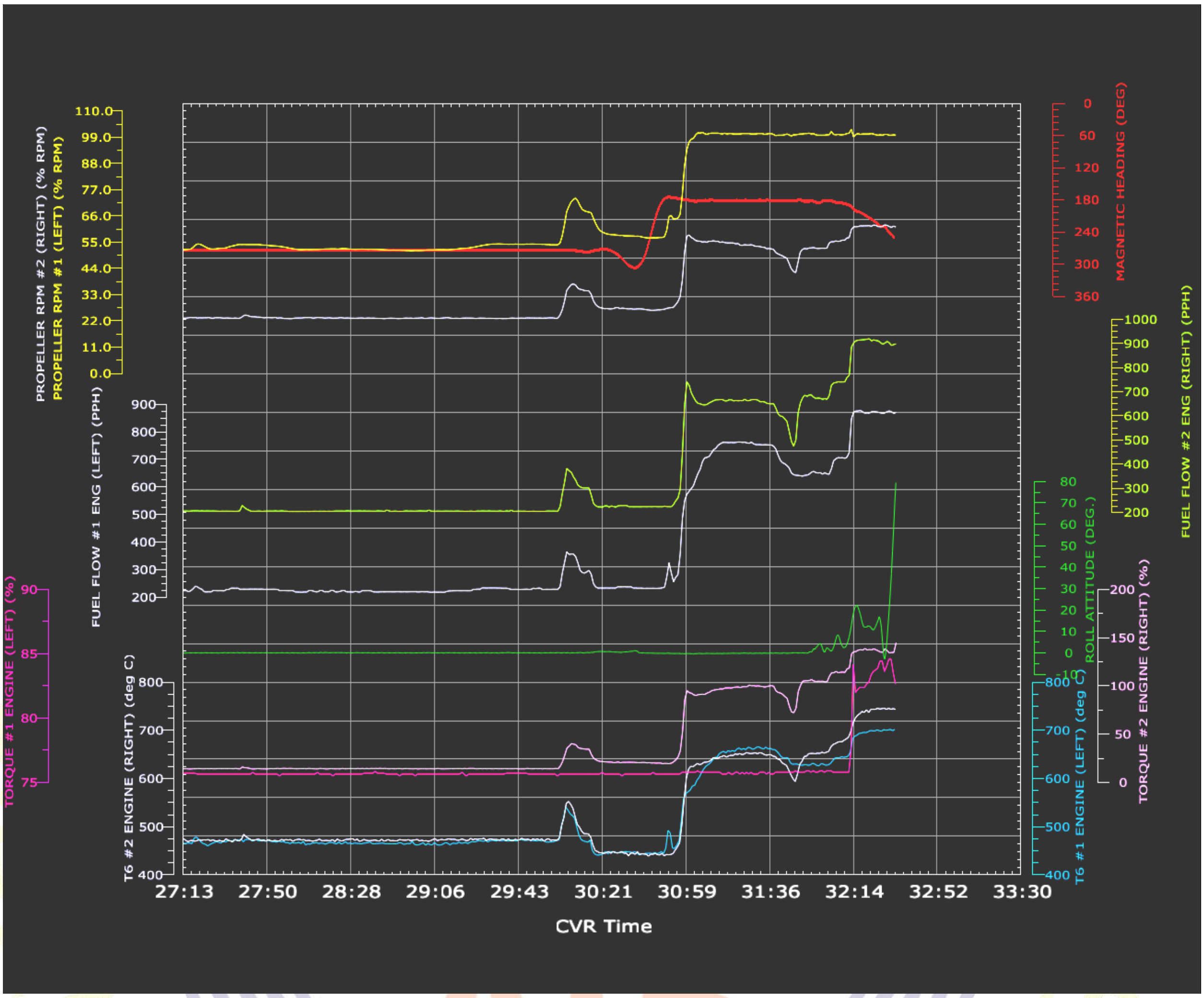


Figure 18: FDR Traces

1.11.5 FDR Readout Analysis

During the take-off roll, the aircraft was aligned with the runway on a heading of 182°. The aircraft then started drifting to the right before rotation. With subsequent rudder correction, the pilot maintained the runway heading until after lift-off when the aircraft veered to the right, as shown above.

During take-off, number 1 propeller RPM was indicating 100% and number 2 propeller RPM was indicating 55%. NH for Engine 1 was 95% RPM and for Engine 2 was 94% RPM. NL for Engine 1 was 92% RPM and for Engine 2 was 93% RPM. The

Roll attitude was maintained at 0° until the stalling point. During the stall, the left wing went up to 80°. The torque for Engine 1 was stuck at 76% and torque for Engine 2 was about 100%. The T6 (temperature) of 620°C for Engine No 1 and 610°C for Engine No 2, with a fuel flow for Engine No 1 of about 750pph and Engine No 2 about 640pph.

From Figure 17, the aircraft was rotated to approximately 13° pitch attitude, attained maximum altitude of 118 feet above the ground where it stalled and impacted the ground at an attitude of 80° bank to the right and a nose-down pitch of -10°.

1.12 Wreckage and Impact Information

The accident occured within the vicinity of the airport where the Joint Users Hydrant Installation (JUHI) is located. The area is a flat grassland with scattered trees and surrounded by fuel reservoirs and a network of pipelines.

During the aircraft's rapid descent to the ground, it first struck a mango tree, brushed and felled some other trees, and then, hit a generator house. The aircraft impacted the ground at a nose-down pitch attitude of -10° and 80° right bank. On impact with a fence in the vicinity, the aircraft broke up into two; forward and rear sections. The forward section was destroyed by the impact forces and post impact fire. The aircraft finally came to rest at a heading of 252°. The propeller blades sheared off from the main hub attachment points and scattered all over the crash site due to impact forces. The rear section was on the other side of the fence and the fire to this section was not as severe; the four survivors were rescued from this area. The Fire Service personnel were able to put off the fire before it could consume the whole rear section.

During wreckage examination the airspeed indicator was reading about 80kts and the flap handle was found to be at the 15° detent.

Figure 19: Flap Gauge Indicating 0^0

The trailing edge flap surface was extended to about 15^o. The right generator switch, the bleed air switch and most of the right engine cockpit switches were in the "OFF" positions. The right engine fire handle was pulled and activated.

Figure 20: Trailing Edge Flap indicating selected Flaps

Figure 21: The No. 2 Fire Handle Pulled and Activated

1.13 Medical and Pathological Information

Following the report of Associated Airlines EMB 120 aircraft accident during take-off out of Lagos airport, a team of Forensic Pathologists from the Lagos State University Teaching Hospital (LASUTH) were invited to the crash site by the Bureau. Medical doctors from the Nigerian Airforce were also at the crash site to render assistance. The wreckage of the aircraft was inspected by the team but the victims and the survivors had already been evacuated to the Lagos State University Teaching Hospital and the Nigerian Airforce Hospital, Ikeja.

Prior to the commencement of the post mortem examination, pathology, radiology and odontology teams were constituted. Thus each body prior to post mortem examination had total body radiological examination and dental charting.

During the examination, adequate attention was paid to the clothings and other personal items recovered from individual bodies as indicated by the doctors. Photographs were taken. "A chunk of iliopsoas and a segment of the ribs were retained in each case for DNA analysis". Samples of the vitreous fluid, venous blood and urine were collected for toxicological analysis. Post-mortem examination was conducted on the 16 fatally injured persons in the crash; fifteen males and one female.

The Pathology report stated that the causes of deaths of the 16 fatally injured persons are as follows:

1.	Multiple injuries following airplane crash	9
2.	Asphyxia following inhalational injury and CO poison	3
3.	Severe craniocerebral injuries following airplane crash	3
4.	Severe cerebral oedema following airplane crash	1
	Total	**16**

The bodies were all identified using a combination of DNA and post mortem examination. They included the pilot, the co-pilot, and the engineer. The results of the toxicological examination on the victims was essentially negative for common drugs of abuse except for the presence of post-mortem alcohol production in blood and urine in one victim and in the blood of another victim. See Appendix E

1.14 Fire

There was no evidence of an in-flight fire during the short flight before the impact. It was a post-impact fire which started after the final impact with the fence. The propagation and extent of the fire was severe, but the fire fighting operation was brief and effective.

The Fire fighting team from JUHI were the first responders on the scene. Three fire fighting vehicles from Airport Rescue and Fire Fighting Services (ARFFS) arrived at the crash–site within 3 minutes due to good access road. The vehicles had Film Foaming Flouroprotain (FFFP) 3% type of extinguisher, 35500 litres of water and 4400 litres of foam which was used for the fire extinguishing operation and was very effective. In addition, water replenishment for cooling was sourced from the Joint Users Hydrant Installation (JUHI).

1.15 Survival Aspects

The crash site was outside the airport premises. The ATC sounded the crash alarm bell and all relevant agencies were notified for search and rescue operations.

The evacuation and rescue operation started within five minutes of impact. The Joint Users Hydrant Installation personnel were already using water from their depot to fight the fire, before the Airport Rescue and Fire Fighting Services (ARFFS) vehicles arrived . The crew and passengers who occupied the front section of the aircraft sustained fatal injuries due to the effects of high impact forces and post-impact fire.

The passengers seated at the rear section of the aircraft survived because there was liveable volume, effective restraint system, and swift rescue operations.

Figure 22: The Aft Section of the Fuselage

1.16 Test and Research

The No. 2 Engine and some aircraft system components were sent to Pratt & Whitney, in the USA and Canada for teardown and analysis.

1.16.1 Propeller Component Visual Examination

The following propeller system components examination was conducted on 13th May, 2015 at the United Technologies Aerospace Systems Customer Training Center in Windsor Locks, Connecticut, USA. The examined components included:

- The Propeller Control Unit (PCU)
- The Propeller Actuator

- The Oil Transfer tube

and

- The Hub

See Appendix A.

Propeller Hub and Control Unit

The disassembly and inspection of the PCU with Part Number 782490-46 and Serial Number 871213 were carried out and the following was revealed:

- The Unit was dirty
- There was a crack that penetrated the housing directly below the Low Blade Angle Switch Connector Housing
- The Ball Screw appears to be in a position that would indicate the blades were within 10 degrees of "Feather"
- Syncrophaser Torque – No visible damage
- The Upper Housing was missing
- The starboard side Condition Lever was bent inward
- The Governor Lock Out Valve was in place and in good condition
- The Beta Light Switch functionally tested normal

The Oil Transfer Tube Part number: 814782-3/Serial number: 760, Hub Part number: 814721-2/Serial number: 673, and Actuator Part number 790199-9/Serial number: 20071213, were removed from a wooden box from Pratt & Whitney Canada. The lid of the box had previously been removed. A visual inspection and measurements of those parts were done. The following observations were noted:

- Pins on the side of the Oil Transfer Tube that go through the Actuator inside the Hub were sheared off. It could not be determined if this was caused by impact damage or disassembly at the time.
- The Actuator Yolk was noted to be in the full aft position, which would indicate the Blades would have been in Feather. The Acme Screw inside the

Actuator was fully screwed out, which could mean the blades might have been in a different position, contrary to the position the Ball Screw in the PCU was found in. This could have been moved on disassembly.

There were dimensions and pictures taken for assessment by Hamilton Sundstrand Engineering,to enable them determine what angle the blades were positioned at the time of the accident.

1.16.2 The Auxiliary Propeller Feathering Pump Test

The auxiliary propeller feathering pump (ACX P/N 4122-009005, S/N 1386) installed on the EMB 120 5N-BJY, was shipped by Pratt & Whitney Canada to Aero Controlex USA for the tear-down, inspection, and testing of the pump. The paper work with the pump stated that it was installed on Pratt Whitney model PW 118 engine with TM S/N 115388 and RGB S/N 115316. It was, however, not clear to ACX if this was the port or starboard engine on the aircraft. See Appendix B for the full report.

Extracts from AeroControlex Tear Down Report:

Conclusion:

1. *The initial visual inspection of the unit showed that the motor was damaged. This damage most likely occurred during impact. The pump sub-assembly was intact.*
2. *The pump sub-assembly was separated from the motor. The pump sub-assembly passed a production ATP. After testing, a detailed teardowm and inspection of the pump sub-assembly's components showed no anomalies. The pump sub-assembly was in good working order at the time of the accident.*
3. *The motor was torn down and the only issue found with the components were related to the impact damage. The impact caused the damage to the motor which caused it to bind.*

4. *AeroControlex has thoroughly evaluated, tested and inspected the returned pump assembly P/N 4122-009005, S/N 1386. The evidence gathered shows that the unit was in good working order prior to the accident on October, 3rd, 2013.*

See Appendix B.

1.16.3 Hydraulic Pump Evaluation

The Hydraulic Pump Evaluation consisted of a factory performance test on the hydraulic pump of the EMB 120 5N-BJY. The report detailed the test results from the factory performance test of the model PV3-022-29 Hydraulic Pump (P/N 570796), S/N MX-467710. See Appendix C for the full report.

Extracts from ETN Service Engineering Report:

Conclusion

The performance of the pump was very good for a pump that had come from a service environment. The pump ran very quietly and all the performance parameters were achieved with the exception of a small deviation in the zero flow pressure (2981psi versus 3000psi). There was no external leakage (parting line or shaft seal) and the full flow was 0.4 gpm greater than the 5.0 gpm requirement.

Based on the performance of the pump, there is no evidence that the pump had an impact on the accident.

1.17 Organizational and Management Information

1.17.1 General

1.17.1.1 Associated Aviation Limited

Description of the Organisation.

Associated Aviation Limited is a holder of an Air Operator Certificate (AOC) No: AAY/C/025, effective date 10th October, 2011 issued by the NCAA with EMB120ER included in their operations specifications (OPSPECS).

Minor checks are carried out in-house, Lagos. Major checks are carried out by Execujet Mtce Pty Ltd, Entrance 1, Lanseria Airport, South Africa.

Associated Aviation Limited was incorporated on the 5th of February 1986.The objective for which it is established includes the following among others;

a. To engage in general business of commercial aviation.

b. To operate international and local cargo air services.

c. To engage in the operation of scheduled international and local passenger flights

d. To operate general air charter services for both local and international arrangement.

e. To engage in business of leasing of aircraft and crew to such persons, company or agency as may require the same.

f. To render third party aircraft engineering and maintenance services as an approved AMO to other airlines.

h. After being approved as a Nigerian Carrier, to train individual and corporate organization in various aviation careers as approved by NCAA.

g. To establish agencies in any part of the country and abroad for achieving any or all the above.

Description of organizational structure

Associated Aviation Limited has in place a functioning management system that has continuity throughout the organization and provides positive control of the operation. This includes a system of accountability to ensure the effectiveness and integrity of the operational management and control system as well as the determination, provision and maintenance of the physical infrastructure and work environment needed to achieve conformity with management system requirements. Responsibility within the management system has been assigned for ensuring compliance with regulatory requirement and established internal standards. The management is headed by a senior corporate official who is the Accountable Manager and has the overall accountability including the authority and control of the resources necessary to finance, implement, and enforce policies and procedures within the operation.

a. The company Board of Directors appoints the Associated Aviation Limited Management.

*b. **The Flight Operations Manager** reporting to the Chief Operating Officer, he is responsible for running the Flight Operations Department in line with the applicable requirement of the Nig.CARs*

*c. The **Chief Engineer** reporting to the Chief Operating Officer, [he] has the responsibility of running the Maintenance and Engineering Department in line with the applicable requirement of the Nig.CARs.*

*d. The **Quality Manager** reporting to the Accountable Manager monitors compliance with the approved procedures to ensure compliance with the applicable Nig.CARs requirements.*

*e. The **Safety Manager** reports to the Chief Operating Officer, [he] and monitors the implementation of the airline safety management programme.*

*f. The **Chief Security Officer** reporting to the Chief Operating Officer, ensures the safe and efficient operation of the security apparatus of the airlines within limits set by professional and mandatory criteria.*

The General Company Organogram is as shown below.

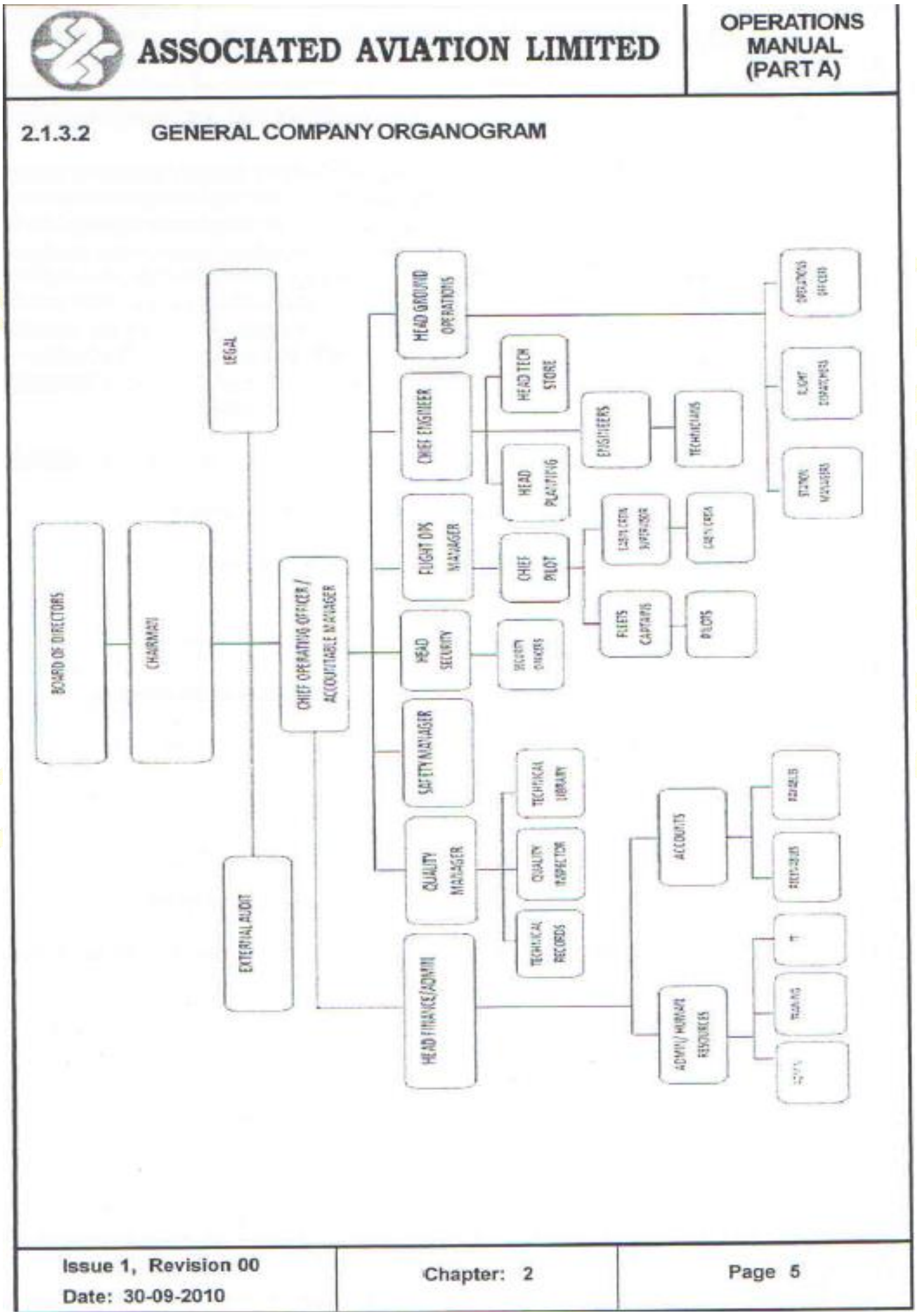


Figure 23: Associated Airlines Ltd Company Organogram

1.17.1.1 Management Policies and Procedures

The following is an extract from the airline's Operations Manual.

1.17.1.2 Extracts from Associated Airlines Operations Manual Part B (SOP)

ENGINE START

CAUTION: ABORT THE ENGINE START BY SELECTING THE START SWITCH MOMENTARILY TO ABORT TO STOP FOR ANY OF THE FOLLOWING REASONS:

- *IGNITION LIGHT DOES NOT ILLUMINATE WITH NH STABILIZES AROUND 25% AND CORRESPONDENT VOLTAMMETER INDICATING 400A;*
- *T6 DOES NOT RISE IN 10 SECONDS AFTER FUEL OPEN;*
- *ABNORMALLY FAST T6 RISE OR T6 EXCEEDING THE LIMITS;*
- *OIL PRESSURE NOT RISING WITH NH AT 45% OR HIGHER;*
- *IGNITION LIGHT DOES NOT EXTINGUISH AFTER 50%;*
- *ABNORMAL SMOKE OR FLAMES COMING OUT OF THE ENGINE EXHAUST PIPE;*
- *ANY UNUSUAL VIBRATION OR NOISE;*
- *ABNORMAL PARAMETERS SHOWING ON THE GAUGES;*

FLIGHT CREW COORDINATION DURING TAKEOFF

When co-pilot is the PF and it is a STATIC TAKEOFF or NORMAL TAKEOFF, the CPT lines up the airplane on the runway, applies brake and calls out "YOUR CONTROLS", the co-pilot responds by applying the brakes too and calling out "MY CONTROLS".

When co-pilot is the PF and it is a ROLLING TAKEOFF, the CPT lines up the airplane on the runway and calls out "YOUR CONTROLS", the co-pilot responds by calling out "MY CONTROLS" without breaking the airplane.

The PF moves the power lever to 10% below the computed torque and calls out "SET TAKEOFF POWER".

The PNF verifies that the torque reached is the target torque and that the engine parameters are normal. If everything is normal, he responds by calling out "TAKEOFF POWER SET".

As soon as the airspeed indicator starts indicating speed the PNF calls out "SPEED ALIVE", as the airplane accelerates past 80KIAS the PNF calls out "EIGHTY KNOTS". The PF verifies that his airspeed indicator is consistent calling out "CHECK".

If the PF is the co-pilot: once the co-pilot has asked "SET TAKEOFF POWER" he moves his left hand from the power levers and holds the yoke with his two hands. By this turn, the CPT moves his right hand to the power levers heads so as to be ready if an RTO becomes necessary. At V1 the CPT moves his right hand away from the power levers.

The co-pilot must immediately report any abnormality that can jeopardize the safety of the flight in a loud and clear voice.

If the CPT decides to abort the take-off he must call out "ABORT" in a loud and clear voice. If the captain decides to continue take-off, he must call out "GO" in a loud and clear voice also.

The take-off emergency and abnormal procedures are described in the respective section.

As the airplane passes V1 the PNF calls out "VEE ONE".

As the airplane passes Vr the PNF calls out "ROTATE".

Once a positive rate of climb is attained the PNF calls out "POSITIVE RATE" and the PF verifies positive rate and calls out: "GEAR UP".

The PNF commands [sic] "GEAR UP" and calls out "GEAR UP SELECTED"

Once the three gear legs indicate up and locked the PNF calls out "GEAR IS UP".

1.17.1.3 Periodic Checks: The following are extracts from approved Associated Aviation Airlines Ltd Operations manual (Mandatory Checks) to be performed by crew.

1.17.1.3.1 Pilots-normal operation (line check):

Every flight crew member is to have been tested in flight to the satisfaction of the Chief Pilot as to his competence to perform the duties required of him in normal maneuvers and procedures, including the use of instruments and equipments provided, in the aircraft type to be used on flights and as described in the Operations Manual Part *A, 6.2.6.2.*

1.17.1.3.2 Pilots-AAL Proficiency Check (Base Check)

Every pilot is to have been tested to the satisfaction of the Chief Pilot as to his competence to perform the duties required of him while executing normal, abnormal and emergency maneouvers and procedures in flight, including the use of instrument approach-to-land systems of the type in use on the route to be flown either:

(1) In flight in the aircraft type to be used, in IMC or IMC simulated by a means approved by NCAA; or,

(2) In a simulator approved by the NCAA, under the supervision of an approved person.

See Operations Manual Part *A,* 6.2.6.3.

1.17.1.3.4 Flight Crew Recency Requirements

a) *A minimum of 6 take-offs, 6 approaches and 6 landings as handling pilot, in an aeroplane or an approved flight simulator of the type to be used, in the preceding 90 days.*
b) *The period in (a) above may be extended up to a maximum of 120 days by line flying under the supervision of a nominated commander.*

See Operations Manual Part *A, 6.2.1.2.*

1.17.1.4 Flight Preparation Instructions

The Captain shall not commence a flight unless he is satisfied that:

i. *The aeroplane is airworthy, duly registered and that appropriate certificates are on board the aircraft. The Captain shall discontinue a flight as soon as practicable when an un-airworthy, mechanical, electrical , or structural condition occurs;*

ii. *Any necessary maintenance has been performed and a certificate of release to service if applicable, has been issued in respect of the aircraft. The PIC has the authority to reject an aircraft prior to departure of a flight if dissatisfied with any aspect of the airworthiness and/or maintenance status of the aircraft.*

AOM Section 8.1(c)(ii)

1.17.2 Nigerian Civil Aviation Autority (NCAA)

1.17.2.1 NCAA Oversight

Civil Aviation is one of the most regulated industries in the world. Every single technical personnel, equipment and airport must be certified and monitored by competent regulatory agencies known as civil aviation authorities. Even the regulators are assessed by International Civil Aviation Organization (ICAO). The operating principles, guidelines and standard applied in Civil Aviation are based on standard and recommended practices (SARPS) of ICAO and stipulated national laws and regulations.

In Nigeria, NCAA is the regulatory body overseeing the activities of all airlines/operators, crew, engineers, navigation aids, all service providers including airport authorities and air traffic services.

1.17.2.2 CRM Requirement

(a) *No person may serve nor may any AOC holder use a person as a flight dispatcher or crewmember unless that person has completed the initial CRM curriculum approved by the Authority.*

See Nig.CARS 8.10.1.12.

1.17.2.3 Aircraft Airworthiness and Safety Precautions

(a) *The PIC may not operate a civil aircraft in flight until satisfied that –*

(1) The aircraft is airworthy, duly registered and that appropriate certificates are aboard the aircraft;

(3) Any necessary maintenance has been performed and a maintenance release, if applicable, has been issued in respect to the aircraft. (b) For commercial air transport operations, the PIC shall certify by signing the aircraft technical log that he or she is satisfied that the requirements of paragraph (a) have been met for a particular flight.

Nig.CARS 8.6.2.1.

1.17.2.4 Compliance with Checklists -

The PIC shall ensure that the flightcrew follows the approved checklist procedures when operating the aircraft.

Nig.CAR 8.5.1.9

1.17.2.5 Compliance with Line (Route and Area Checks) – Pilot Qualification -

(a) No person may serve nor may any AOC holder use a person as a pilot unless, within the preceding 12 calendar-months, that person has passed a route check in which he or she satisfactorily performed his or her assigned duties in one of the types of aeroplanes he or she is to fly.

Nig.CARs 8.10.1.30

1.18 Additional Information

1.18.1 Torque Meter Assembly

The torque meter assembly is located between the power section and reduction gear assemblies. Its purpose is to transmit and measure the shaft output from the power section to the reduction gear assembly.

The torque meter operates on the principle of accurate measurement of torsional deflection (twist) that occurs in any power transmitting shaft. This torsional deflection is detected by magnetic pickups. The deflection is measured electronically and displayed in the flight station instrument panel in terms of inch-pounds of torque, or shaft horsepower (SHP). The principle parts of the torque meter assembly are shown in *Figure 24.*

Two concentric shafts make up the torque meter assembly. The inner shaft (torque shaft) carries the load and produces the measured twist. The outer shaft (reference shaft for measuring purposes) is rigidly connected to the torque shaft at the drive input end only. There are separate flanges on both the torque and reference shafts at the reduction gear assembly end. Rectangular exciter “teeth” are machined in line on each flange, which enable the pickups9 to detect the relative displacement of the two flanges.

The torque meter housing serves as a rigid lower support between the power unit and the reduction gear assembly. It provides a mounting for the pickup assembly at the reduction gear end.

The pickup assembly consists of electromagnetic pickups mounted radially over the teeth of the torque and reference shaft flanges. These pickups produce electrical impulses at the passage of each exciter tooth. The pickups are displaced so that the reference flange impulse from its pickup and the torque flange impulse from its pickup are slightly out of phase at zero load. Because zero torque indications are not at the electrical zero of the indicator, both positive and negative torque conditions are measured.

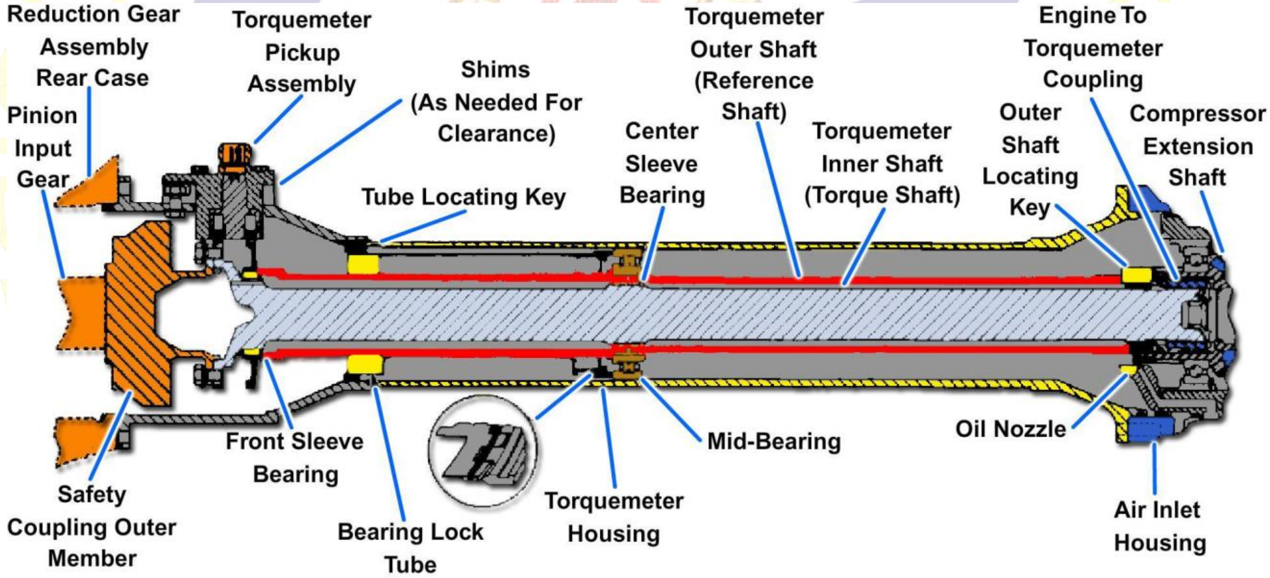


Figure 24: Torque Meter Assembly

1.18.2 Pre-Departure Checks

During interview with the engineers of Associated Airlines, it was revealed that pre-departure maintenance check is required to be carried out prior to first flight of the day by an appropriately authorised maintenance personel, who releases the aircraft to service using the Pre-Departure Check Card. The same engineer who releases the aircraft to service is expected to countersign pre-departure card.

1.18.3 Crew Resource Management (CRM)

This is a set of training procedures which encompasses wide range of knowledge, skills and attitude including communication, situational awareness, problem solving, decision making and team work. Its use is primarily for improving air safety.

1.19 Useful or Effective Investigation Techniques

Nil.

2.0 ANALYSIS

2.1 General

Associated Aviation Ltd is certified to operate aircraft in commercial air transport as an AOC holder. The aircraft had a valid Certificate of Airworthiness, however certain descrepancies were recorded by the flight recorders with no relevant entries in the Tech Log were made. The crew were certified to conduct the flight, though the PF recency has expired on 1st August, 2013. There was no reported adverse weather condition on the day of the occurrence, therefore weather was not considered to be a factor.

2.2 Conduct of the Flight

The flight was scheduled to depart for Akure at 0930hrs as a charter flight SCD361 on the 3rd October 2013. The flight crew boarded the aircraft, where-in they entered into an extensive discussion, expressing concerns about the suitability of the aircraft for the flight. Some of the discussion was in the Yoruba language, which was non-standard practice. Contact was established with Lagos Ground Control; flight information, destination-Akure, FL190 and start-up request was made. Flight plan was confirmed and start-up was granted.

Several factors could have contributed to the aircraft's speed not being sufficient for the pilot to maintain control of the aircraft after rotation. These factors included the significant loss of power from the right engine on initial roll, resulting in slow acceleration and substantial aerodynamic drag from the landing gear remaining extended. Also, the propeller was not conclusively confirmed to be feathered from the test analysis.

In addition, the aircraft's speed when it became airborne, was probably not close to airborne minimum control speed (V_{mca}) which was not sufficient for aircraft acceleration to the best one-engine inoperative rate of climb speed (V_{yse}) with an engine failure.

2.2.1 Torque Indications

After engine start, No. 1 Engine Torque Indicator was stuck at 76%. Normally, the torque indication should have been 22% at engine idle. At this point the crew tried to correct the situation by carrying out the EEC test but the problem persisted. This should have necessitated the crew shutting down the engine and calling Maintenance in accordance with Company SOP. Rather, they decided to continue without reference to the approved Minimum Equipment List (MEL) as required. The MEL does not allow the continuation of a flight with an inoperative Torque Indicator.

During taxi, the crew had indicated that, for the purpose of circumventing what they thought was an EEC problem, they would use T6 which is the engine temperature indicator to set the take-off power. The engine temperature parameter is used to trim engine power output during high engine power operations like take-off and go-around. Engine temperature indicator should not be used to set take-off power as there is no approved procedure for using T6. This demonstrated the crew's inadequate system knowledge and/or deliberate disregard for procedures.

2.2.2 Take – Off Flaps Configuration Warning

Take-off Flaps aural warning is a take-off configuration warning which indicates that the flaps are not in the correct position for take-off.

During taxi, Take-off Flaps (15^0) was selected by the crew and the indications were normal at this point. However, there was some evidence from the CVR transcript that the crew agreed that if the Take-off Flaps aural warning came on during the take-off roll, they will perform a flapless take-off "again". This suggested that the crew had previously performed a flapless take-off. There is no flappless take-off procedure in the Operations Manual/SOP.

During the take-off roll, there was continous "Take-off Flap" configuration warnings which the crew disregarded and continued the take-off roll. The take-off should have been aborted at this point.

2.2.3 Auto-Feather Warning on Take-off

"Auto Feather" aural warning is an indication to the crew that the auto feather system is not available. After setting take-off power, the "Auto Feather" aural warning came on. At this point the crew should have aborted the take-off but elected to continue and ignored the warning.

2.2.4 No 2 Propeller RPM Indication during Take-off

During take-off, No. 1 Propeller RPM was indicating 100% and No. 2 Propeller RPM was indicating 55%. Fuel flow for Engine No 1 of about 750pph and Engine No 2 about 640pph. All other parameters for both engines were within limits. The No. 2 Propeller RPM was too low, which should have necessitated the crew to abort the take-off.

Examination of No. 2 Propeller Control Unit (PCU) Ball Screw indicated a propeller blade angle of about 10^0 to feather position which is not consistent with a blade angle of selected condition lever (max RPM) for take-off power.

The discrepancy between the actual No. 2 Propeller angle and the angle commanded by the crew is a strong indication that there was a malfunction inside the PCU as at the time the take-off power was set, which led the No. 2 Propeller to have an uncommanded high blade angle.

This investigation could not determine the reason for the PCU action which led to the low propeller RPM during take-off.

2.2.5 Engine

Engine Tear Down: The investigation of the RH engine did not reveal any evidences of pre-impact anomalies or defects and/or mechanical deterioration that would have precluded normal operation performance and control response of the engine. All evidences of the investigation showed that all the rotor spools of the RH engine were rotating under power and operating before and during the aircraft impact sequence.

The investigation of the LH engine and EEC revealed no evidence of pre-impact anomalies or defects that would have precluded normal operation performance and control response of these external accessories before the aircraft mishap.

FDR readout revealed that following during take-off: NH for Engine 1 was 95% RPM and for Engine 2 was 94% RPM. NL for Engine 1 was 92% RPM and for Engine 2 was 93% RPM. The torque for Engine 1 was stuck at 76% and torque for Engine 2 was about 100%. The T6 (temperature) of 620°C for Engine No 1 and 610°C for Engine No 2, with a fuel flow for Engine No 1 of about 750pph and Engine No 2 about 640pph.

For full Engine Teardown Report refer to the **Appendix**.

2.3 The Crew

2.3.1 Simulator Recurrency

The crew licences and medicals were valid. However, the PF was not certified to conduct the flight due to the validity status of his simulator recurrency. The PM flew last on 31st July, 2013; 64 days before the accident. The recurrency check submitted to the NCAA for renewal of his licence was signed by the Captain of the accident flight. However, there was no recorded evidence to show that the Captain was certified to carry out that proficiency check because he did not have current Check Airman Authorisation.

2.3.2 Route Check

The Captain operated this accident flight without a check ride. There was also no documented evidence to show that the crew complied with the NCAA training and check requirements nor the AOC holder, as there were no evidences of route checks, route familiarisation and proficiency checks in the year 2013. These were not in compliance with the following: NigCARs ref. 8.10.1.30(a) *No person may serve nor may any AOC holder use a person as a pilot unless, within the preceding 12 calendar-months, that person has passed a route check in which he or she satisfactorily performed his or her assigned duties in one of the types of aeroplanes he or she is to fly.*

2.3.3 CRM

From engine start-up to when the aircraft was cleared to line up on Runway 18L, the crew were pre-occupied with concern and uncertainty centered around the aircraft airworthiness status to operate the flight. Without any reference to the Technical Log Book where aircraft snags are detailed with the associated repair work performed by the Engineers, the PF decided to operate the flight without conclusively resolving their concerns about the EEC but the PM instead suggested the use of T6 to set the engine power which is inappropriate.

During the take-off roll, there were continous take-off flaps, auto-feather automated voice warnings and Propeller No. 2 low rpm indication which the crew did not respond to but instead, continued the take-off roll. "Take-off Flaps" warning is a take-off configuration warning which indicates that the flaps are not in the correct position for take-off. There were some evidences from the CVR transcript that the crew indicated and have infact elected not to use flaps for the take-off when the PF stated during the taxi that if the flap warning came on during the take-off roll, they will perform a flapless take-off "again". This suggested that the crew had performed a flapless take-off before, but there is no flappless take-off procedure in the Aircraft Flight Manual nor the Operations Manual/SOP.

The crew exhibited a high level of poor professional judgement and airmanship coupled with a flight crew omissions and inappropriate actions as a result of inadequate systems knowledge and most importantly the significannce of the three mandatory speed call-outs. Finally, the PF rotated the aircraft as the end of the runway was fast approaching without mandatory call-out of V_1 and V_r.

2.4 Human Factors

There had been and will always be hazards, both real and potential, associated with the operations of an aircraft. Technical, operational, weather and human failures otherwise known as human factors induce the hazards. This accident showed the man-machine relationship which in turn included the actions and inactions of the crew present in the events that surrounded the occurrence. It covered how the flight crew members analysed, reacted and attempted to cope with all the complexites of the flight. The investigation explored all aspects related to the crew's handling of the aircraft which fell into the categories of Company Culture, Training, Operations and Supervision.

2.4.1 Company Culture

The Bureau discovered that the aircraft had not been operated for flight for almost one year and it was being brought back to service. It is evident that there was company pressure on the crew to operate the aircraft on that day, not minding all indication and warnings to the crew, they still decided to carry on with the flight. The investigation also discovered that the staff of the company had not been paid for sometime before the flight. The company was contracted/chartered to conduct the flight. The company must have desperately wanted to conduct the flight to justify the payment received, this in turn influenced the crew to insist on conducting the flight despite the fact that it was apparent to them that the aircraft was not airworthy.

2.4.1.1 The Operator

The handling of the accident flight by the crew calls to question the quality of their training and the organization's safety culture. The absence of CRM training was evident in the operational behaviour and the lack of crew coordination in terms of briefing, call-outs, checklist usage, decision making and assertiveness.

The company's management supervision was lacking in terms of Orders, Standards and Procedures, which had direct bearing on the accident.

The following are obvious shortcomings noticed in this investigation:

1. Non-compliance with NCAA regulatory requirements,
2. Inability of the operator to enforce the requirements of its OPs manual in terms of training, and required checks such as recency, proficiency, etc, in compliance with the Nig.CARs 8.10.1.30(a),
3. Absence of CRM training of the crew,
4. Poor maintenance culture and,
5. Company pressure on the crew.

Another evidence of inadequate and inappropriate level of the crew's training was when both crew agreed that they could set the take-off power using the T6; which is the temperature indication.

The PF was the Company's Operations General Manager and at the same time a Training Captain but he was unable to cope with the attached responsibilities of supervision. However, there was no documented evidence to support the second position.

2.4.2 Training

The company did not put a system in place to ensure that flight operations personnel that are out of compliance cannot be scheduled for flights.

There was no documented evidence to indicate that the crew complied with the CRM requirements both initial and recurrent, which did not comply with Nig.CARs

8.1.12(a) which states that *no person may serve nor may any AOC holder use a person as a flight despatcher or crewmember unless that person has completed the initial CRM curriculum approved by the Authority.*

Also from the records available to the Bureau, there was no documented evidence to show that the crew of the accident flight complied with the Nig.CARs reference 2.3.1.6(a) which stipulates as follows: *A pilot shall not operate an aircraft carrying passengers as PIC or co-pilot unless he or she has carried out at least three take-offs and three landings as pilot flying in an aircraft of the same type/class or variant of a type or a flight simulator of the aircraft/type to be used, in the preceding 90 days.*

Assertiveness, effective monitoring and challenging of procedures by the PM was completely absent in this attempted take-off which tantamounts to crew-member's failing to discharge individual responsibility. If the preventive risk controls fail, recovery risk controls are an important last line of defence which the crew should have used to mitigate the severe conseqences of this take-off attempt.

2.4.3 Operations

It was unlikely that any medical or physoiogical factors adversely affected the pilot's performance.

According to the CVR transcript, the Captain made all the decisions, flew the aircraft at the same time, disregarded the few unassertive call-outs by the First Officer who rarely challenged the Captain's flawed decisions. This was not in compliance with the First Officer's responsibility, ref. 1.5.1(b) 2(b) of the approved Operations Manual: *…".a hazardous situation is developing, Captain to be informed by the co-pilot."* The First Officer advised that the take-off should be aborted but the Captain elected to continue the take-off roll.

This occurrence had revealed the need for formal policies and programs to be adopted by the Authority (NCAA) to ensure aircrew function well as a team, with each one having defined complementary duties rather than the Captain always in the lead with different ideas.

Finally, at this point, the Bureau believed that the crew had exhibited a high level of poor professional judgement and airmanship, coupled with inappropriate actions as a result of inadequate systems knowledge.

2.4.4 Supervision

The Captain occupied two senior positions in the Company's Management framework but he was unable to cope with all the attached responsibilities of supervision. According to the NCAA approved Operations Manual Part A section 2.1.1, the Operator, Associated Aviation Airlines Ltd *shall establish and maintain a method of supervision of flight operations approved by NCAA* and reference to the approved Operations Manual, ref. *2.1.3 states that the supervision of the competence of the operations personnel is achieved by ensuring that the personnel assigned to, or directly involved in, ground and flight operations are properly instructed and have demonstrated their ability in their particular duties*. There was no documented evidence that these requirements were complied with. According to the airline's Chief Operating Officer, there was no other EMB 120 type rated training Captain in the airline who can perform the NCAA mandatory Pilot Checks for this Captain.

There are many aspects of the supervisory processes which had direct bearing on the accident, such as provision and acceptance of inadequate flight crew training which had contributed to the crew in not maintaining the required NCAA Standards/Requirements and failure to have performed proper training in aircraft type, nil/shortcomings in crew resource management, and unreasonable pressure on crew to undertake flights with uncertainty of aircraft airworthiness and maintenance status.

2.5 NCAA Oversight

During the course of the investigation, the Bureau observed that the aircraft C of A was renewed by the NCAA with a validity of three months as against the normal practice of twelve months. A review of the aircraft C of A File obtained from NCAA could not reveal the reason for the above.

According to records available, the crew had valid licenses. However, there was no evidence of their currency in terms of Recency, CRM and other training that were necessary qualifications to conduct the flight.

NCAA oversight on Associated Airline Limited in terms of the crew qualifications was inadequate. This could have addressed all the issues pertaining to training and currency of the crew before the accident.

The Captain operated this accident flight without a current simulator training and he did not comply with any of the NCAA mandatory checks in 2013. It was observed from the records available to the Bureau, that Associated Aviation safety culture forstered negatively on the accident and attendant NCAA oversight function to provide timely and effective oversight which would have made it possible to discover early the inadequate flight crew training and system knowledge.

3.0 CONCLUSIONS

3.1 Findings

1. The aircraft had a valid Certificate of Airworthiness with a validity of three months from the date of issuance.
2. During wreckage examination the flap handle was found to be at the 15º detent, the airspeed indicator was reading about 80kts and landing gear in the DOWN position.
3. It was discovered after engine start that Engine No. 1 Torque Indicator was unserviceable.
4. The crew did not comply with recency requirements.
5. The PF simulator recurrency status was not valid at the time of the accident.
6. The PM was licenced and medically fit to operate the flight.
7. There was no evidence of CRM training by the flight crew.
8. The crew agreed that they can set the takeoff power using the T6 indication, which is the temperature indication.
9. There was inadequate application of Crew Resource Management (CRM) principles.
10. During the take-off roll, there were continous Take-off Flaps configuration and Auto-Feather warnings which the crew did not respond to.
11. The PM did not make V_1 and V_R call-outs before the PF rotated the aircraft.The response to the standard call-out of "80kts" made by the PM was not in accordance with the SOP.
12. The aircraft was rotated before V_1.
13. There was insufficient height and power available to effect a recovery from the stall.
14. The abnormal manoeuvre of the aircraft during the initial climb prompted the ATC to inquire from the crew if "OPs normal" but there was no response.
15. The investigation revealed a poor organisational culture and non-compliance with regulatory requirements.

16. The company did not put a system in place to ensure that flight operations personnel that are out of compliance cannot be scheduled for flights.

3.2 Causal Factor

i. The decision of the crew to continue the take-off despite the abnormal No. 2 Propeller rpm indication.

ii. Low altitude stall because of low thrust at start of roll for take-off from No. 2 Engine caused by an undetermined malfunction of the propeller control unit.

3.3 Contributory Factors

1. The aircraft was rotated before attaining V_1.
2. The decision to continue the take-off with flap configuration warning and auto-feather warning at low speed.
3. Poor professional conduct of the flight crew.
4. Inadequate application of Crew Resource Management (CRM) principles.
5. Poor company culture.
6. Inadequate regulatory oversight.

4.0 SAFETY RECOMMENDATIONS

4.1 Safety Recommendation 2017-020

NCAA should enhance the enforcement of the regulations with regards to the implementation of operators approved personnel training program.

4.2 Safety Recommendation 2017-021

NCAA should intensify its safety oversight function on the Airline to ensure that flight operations are carried out in accordance with approved operations manuals in line with the provisions of Nig. CARs.

4.3 Safety Recommendation 2017-022

NCAA should intensify its safety oversight on Associated Aviation Ltd to ensure staff welfare issues, and remunerations are settled promptly.

4.4 Safety Recommendation 2017-023

NCAA should ensure that State Confidential Voluntary Reporting System is established and implemented in line with the State Safety Program.

RESPONSES TO SAFETY RECOMMENDATIONS

NCAA Response on AIB Safety Recommendations

1. NCAA responded to Safety Recommendation 4.1 (2017-020) as follows:

The NCAA as the body designated with the responsibility for safety oversight of certified entities and the enforcement of the regulatory requirement, develops and implements surveillance programme to ensure operators continue to maintain the required standards to which they had been certificated. The Authority heightens its surveillance activities whenever trends of infractions, non-conformances to approved procedures are observed. When non-compliances are detected, the Authority will, through its resolution of concerns processes ensure that operator develops and implements appropriate corrective action plans to address observed deficiencies and when necessary, the Authority may carry out its enforcement procedures.

2. NCAA responded to Safety Recommendation 4.2 (2017-021) as follows:

NCAA implements its surveillance activities using appropriate tools that include but not limited to audits, surveys, spot checks, unscheduled inspections etc., to ensure that operations are accomplished in accordance with the requirements of the Nig. CARs and organisations' approved procedures.

3. NCAA responded to Safety Recommendation 4.3 (2017-022) as follows:

The AOC issued to Associated Airlines has been withdrawn by the Authority. However, records of meetings the Authority held with the management of certified organisations whenever it receives reports of non-settlement of staff welfare and remunerations are available.

4. NCAA responded to Safety Recommendation 4.4 (2017-023) as follows

The NCAA agrees with this recommendation. The Authority has reached an advanced stage in the implementation of the Nigeria's Voluntary and Confidential Reporting System (NVCRS), with the development of the draft and the designation of administrators to manage the system.

APPENDICES

APPENDIX A: Factual Notes, 14RF-9 Propeller component visual examination in Support of the investigation of Associated Airlines EMB120, Reg 5N-BJY

FACTUAL NOTES, 14RF-9 PROPELLER COMPONENT VISUAL EXAMINATION IN SUPPORT OF THE INVESTIGATION OF ASSOCIATED AIRLINES EMB120 REG 5N-BJY

1.0 Investigation Participants

The following propeller system component examination was conducted on May 13, 2015 at the United Technologies Aerospace Systems Customer Training Center in Windsor Locks, Connecticut, United States of America. The following individuals participated in the examination as representatives of their respective organizations.

M	Service Engineer, United Technologies Aerospace Systems
F	Air Safety Engineer, Embraer
S	Aviation Safety Inspector, Federal Aviation Administration
D	Aviation Safety Inspector, Federal Aviation Administration

2.0 General Background Information

The 14RF-9 Model is a variable pitch aircraft propeller, manufactured by Hamilton Sundstrand, a Division of United Technologies, based in Windsor Locks, CT, USA. The propeller is 10.5 feet in diameter.

3.0 Model Designation 14RF-9

The first digit, 1, denotes major model type; the second digit, 4, denotes the number of blades. The letter R designates the propeller blade shank size. The letter F denotes a flange mounted propeller. The dash number (-9) denotes a specific application within the model type. Note: The convention for this propeller is that blade angles given are with reference to the 42.0 inch station (ß42 = 42 inches from propeller center line).

4.0 Propeller Component Data

4.1.a 14RF Propeller Control Unit (PCU)

Part Number 782490-46
Serial Number 871213

The propeller control was received without the adapter housing, but was otherwise complete (Figure 1). The unit was dirty and suffered an impact which damaged the main housing adjacent the beta light connector (Figure 2). This damage prevented testing the PCU on a hydraulic test stand due to the possibility of metal contamination of the test stand. The visual inspection also revealed a bent starboard condition lever (Figure 3).

U.S. Export Classification: EAR 9E991

The ballscrew was measured to correlate the position to a blade angle (Figure 4). This position equals approximately 70.5 degrees β42 (Feather = 79.2 degrees β42).

The primary quill (Figure 5) was removed to enable an examination of the quill and ballscrew splines. No measureable wear was noted on the internal primary quill splines (Figure 6) and external primary quill splines (Figure 7). The ballscrew internal splines were in good condition and no measureable wear was observed (Figure 8).

The upper housing was removed to gain access to the interior of the PCU (Figure 9). No visible damage was noted. The governor lockout valve was confirmed to be the latest configuration, with the locking pin present (Figure 10). The presence of the secondary drive quill and beta light functionality (on/off only) were also verified.

4.1.b 14RF Propeller Actuator

Part Number 790199-9
Serial Number 20071213

The actuator was still installed in the propeller hub (Figure 11). The spinner bulkhead was bent over and obscuring the dome of the actuator. The yoke was fully aft (Figure 12), which correlates to the feather position. There was significant damage to the yoke and wear plate area from the blade trunnion pins and bearings. The tailshaft was broken from the yoke (Figure 13, note: pitchlock screw placed in feather after position measurement to improve view).

While the yoke was in feather, the Pitchlock screw was not against the feather stop (Figure 14). The Pitchlock screw was in a position of 4.0625-inches from the face of the pitch lock nut. This position does not correlate to an operational blade angle. The working limit of the Pitchlock screw in reverse is approximately 3.530-inches from the face of the pitchlock nut.

4.1.c 14RF Oil Transfer Tube

Part Number 814782-3
Serial Number 760

The transfer tube assembly was included with the investigation hardware, but not installed. The transfer tube and splines (Figure 15) were in good condition with the exception of the retainer. Both of the retention tabs were broken off of the retainer. In addition, the cotter pin was still installed in the retainer (Figure 16). This cotter pin must be removed to facilitate proper disassembly.

4.1.d 14RF Hub

Part Number 814721-2
Serial Number 673

The hub was returned with the actuator still installed. The four arm bores had damage consistent with an impact. No other significant observations were noted.

U.S. Export Classification: EAR 9E991

Figure 1. Propeller Control 871213 in as received condition.

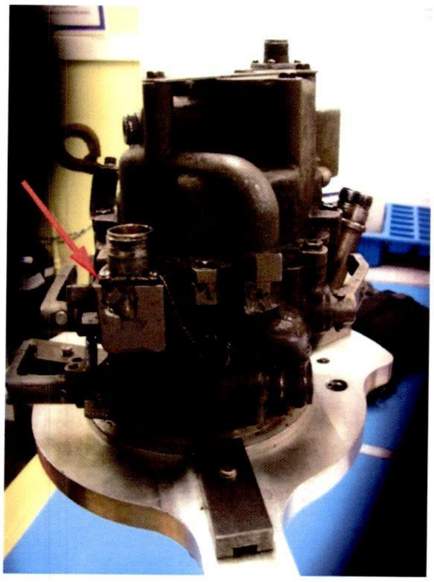


Figure 2. PCU Housing damage.

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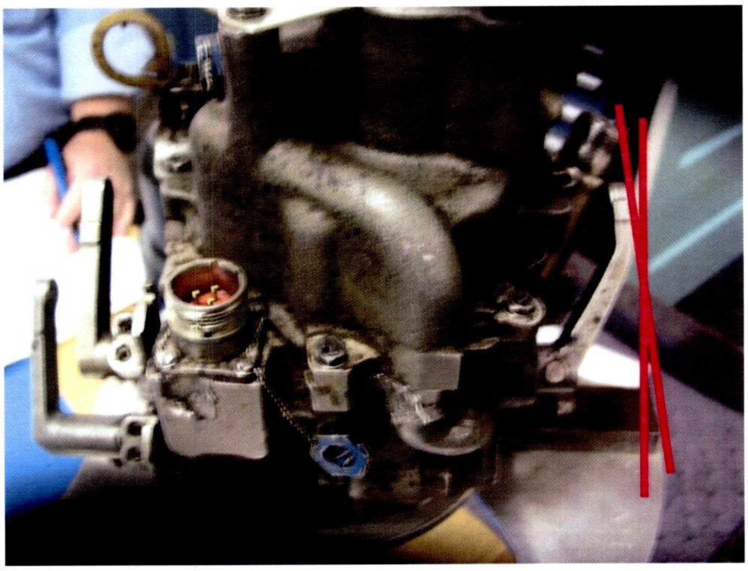

Figure 3. Bent Power Lever.

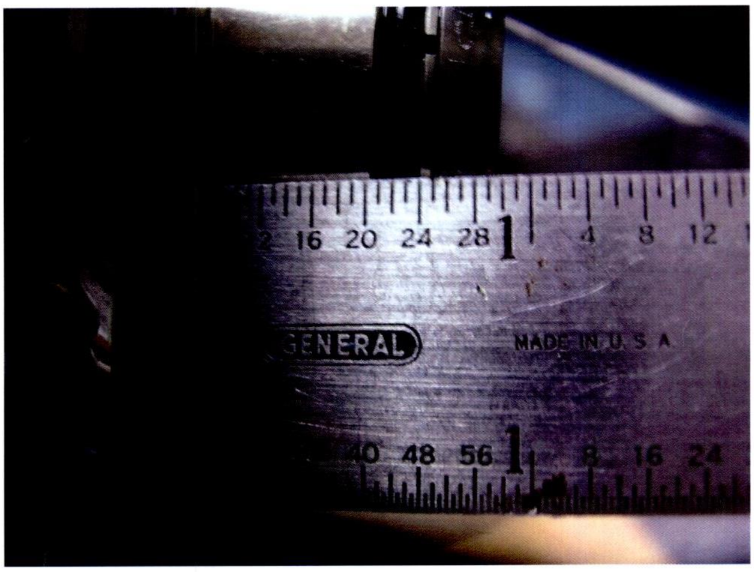

Figure 4. Ballscrew position.

U.S. Export Classification: EAR 9E991

Figure 5. Ballscrew Primary Quill.

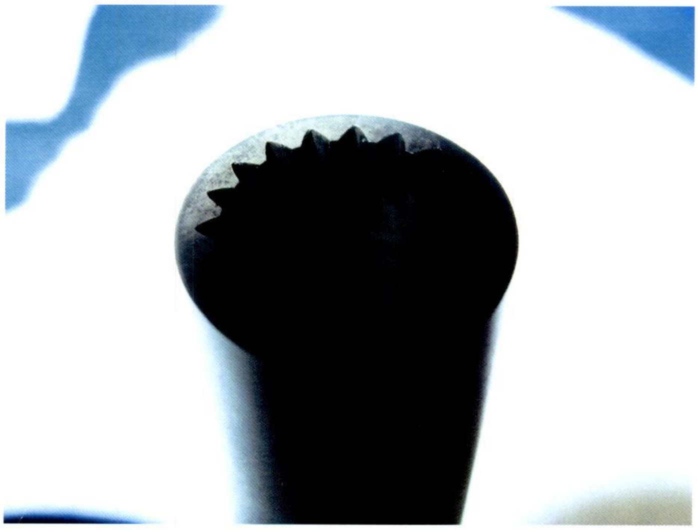

Figure 6. Internal Primary Quill Splines.

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Figure 7. Primary Quill External Splines

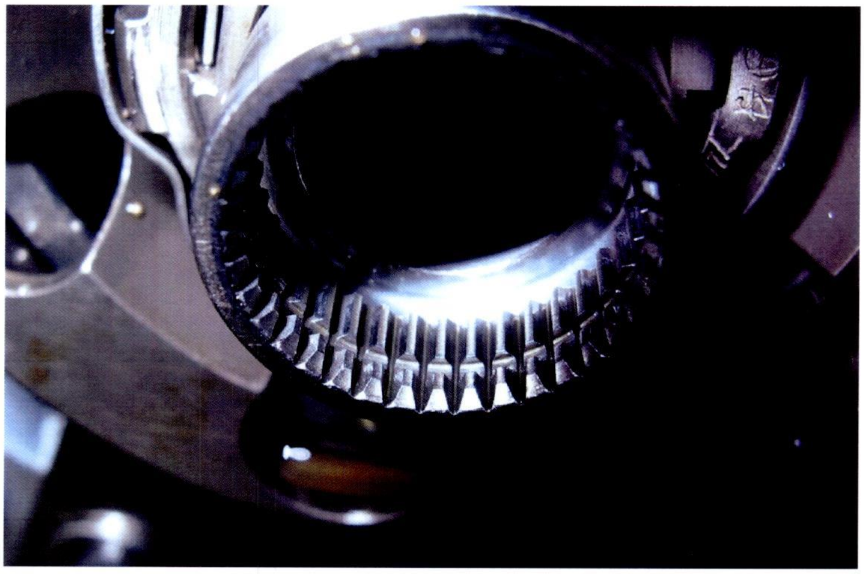

Figure 8. Ballscrew Internal Splines

U.S. Export Classification: EAR 9E991

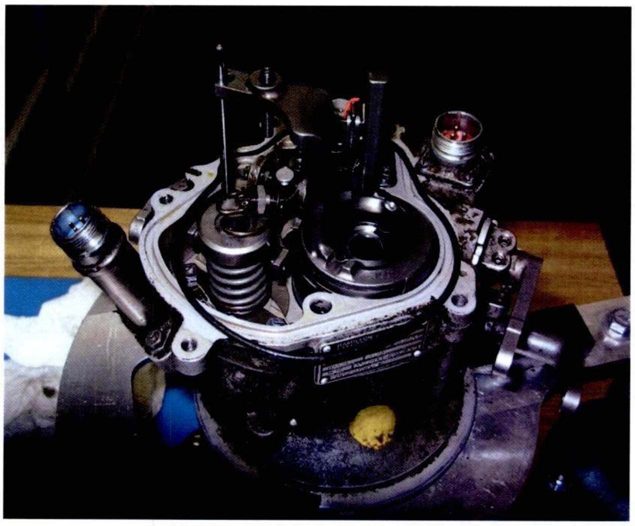

Figure 9. PCU Upper Housing Removed.

Figure 10. Governor Lock Out Valve Retention Pin.

U.S. Export Classification: EAR 9E991

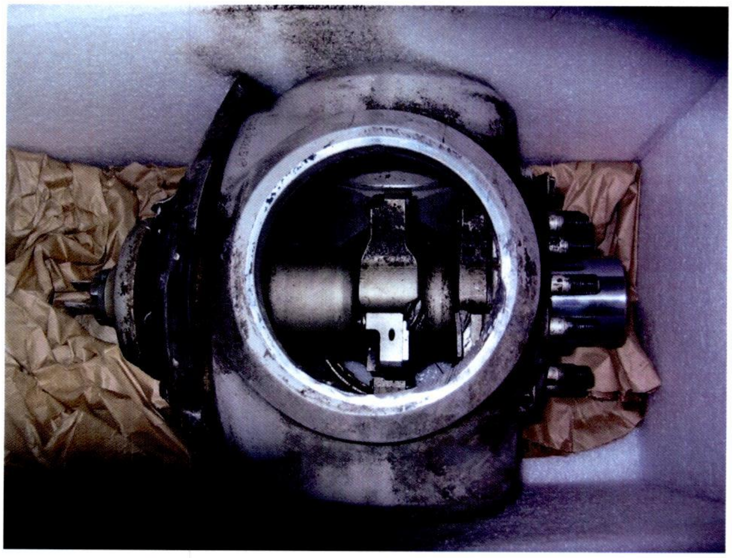

Figure 11. Hub and Actuator Assembly as-received condition.

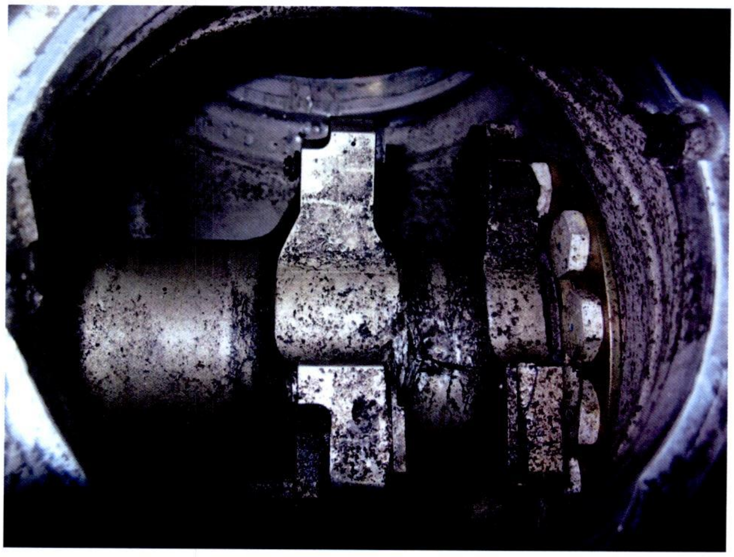

Figure 12. Actuator Yoke Position.

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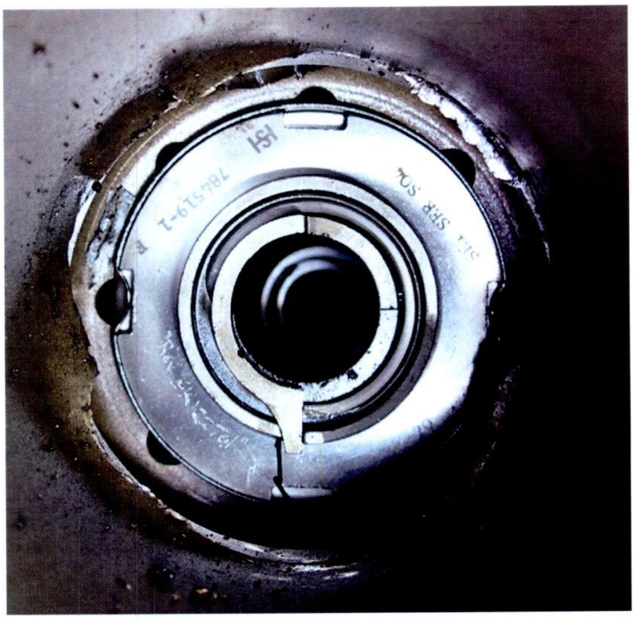

Figure 13. Broken Actuator Yoke Tailshaft.

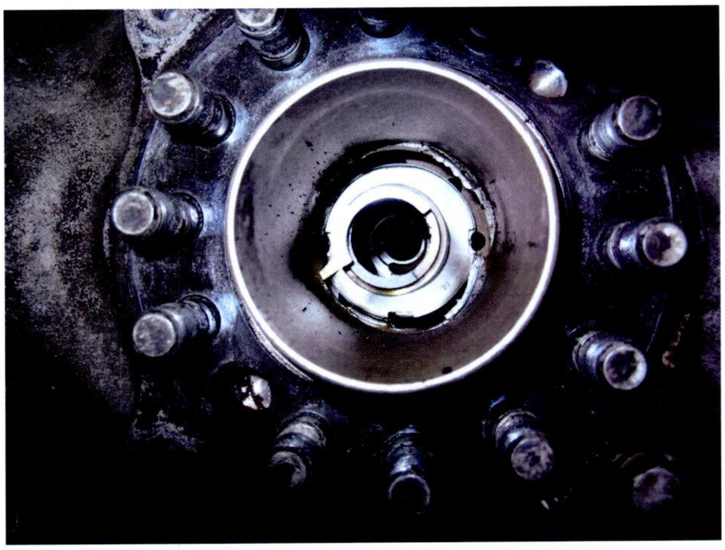

Figure 14. Pitchlock Screw Position.

U.S. Export Classification: EAR 9E991

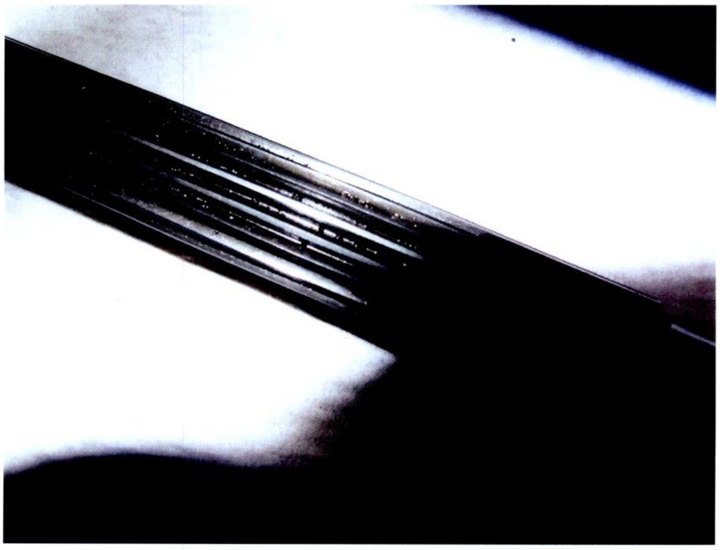

Figure 15. Transfer Tube Splines.

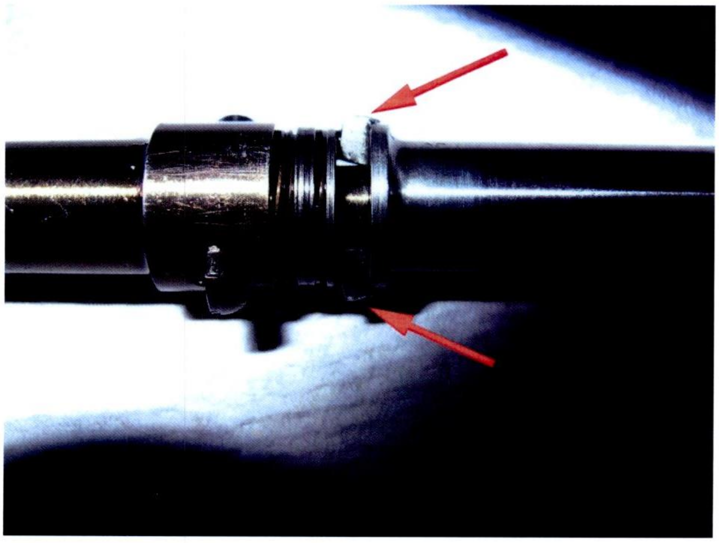

Figure 16. Broken Transfer Tube Retainer Tabs.

U.S. Export Classification: EAR 9E991

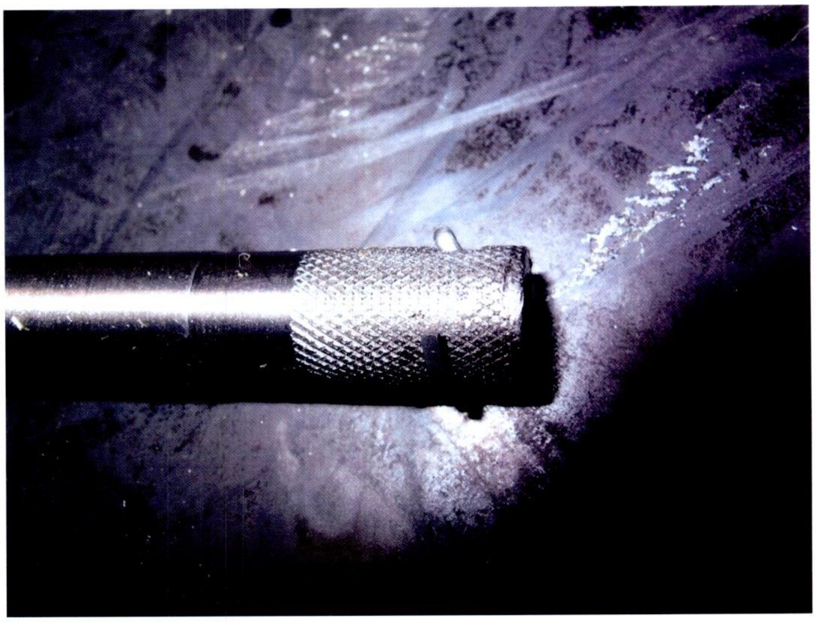

Figure 17. Transfer Tube Retainer Cotter Pin.

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Engine Tear Down Report

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Associated Aviation Limited
Embraer EMB 120 Brasilia Aircraft
Registration No. 5N-BJY
Lagos, Nigeria
October 3, 2013
PW118
Right Hand (RH) Engine S/N's 115388 (TM) / 115316 (RGB)
&
Torque Signal Conditioner (TSC) S/N MM4896 & Engine Electronic Control (EEC) S/N 9090010 of Left Hand (LH) Engine S/N AA0045

Written by:
Technical Staff Representative - Investigator, Service Investigation Department

Approved by:
Manager, Service Investigation Department

Date of Issue: **December 3, 2014**

Distribution:

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I ANALYSIS

1.0 Accident Synopsis

1.1 Reportedly, the Associated Aviation Embraer EMB-120 aircraft registered 5N-BJY was performing a charter-flight from Lagos to Akure, Nigeria with 20 people on board, including family members and the deceased former Aviation Minister Olusegun Agagu. Shortly after takeoff (TO) on runway 18L of Murtala Muhammed International Airports (Lagos), the aircraft was able to maintain airborne lift and subsequently the aircraft impacted the ground resulting into the aircraft breakage and caught fire followed by several casualties.

2.0 Summary of Findings & Discussions

2.1 The RH engine received within its impact-battered aircraft nacelle. It was composed of the turbomachine module (TM) S/N 115388 mated with the reduction gearbox module (RGB) S/N 115316. In addition, the TSC S/N MM4896 and EEC S/N 9090010 of LH Engine S/N AA0045 were received separately within the wooden cradle of the RH engine.

2.2 The investigation of the LH engine and of the RH engine accessories components were oversight by the Accident Investigation Bureau (AIB) of Nigeria.

2.3 There was no engine log book received and/or availability of the maintenance and elementary service records on the LH and RH engines.

2.4 The airframe accessories controls components such as the Propeller Hub and rod, Propeller Control Unit (PCU), Auxiliary Feathering Pump and Variable Delivery Hydraulic Pump (VDHP) were sent for investigation to their respective suppliers that oversight under jurisdiction of the Nigerian AIB.

2.5 Examination of the RH engine external and accessories did not exhibit any signs of fire damage before and/or after the aircraft impact sequences but found dirty and sooty.

2.6 Disassembly examination of the RH engine had shown a severance of the balancing torque shaft assembly linking the RGB input shaft drive coupling and the power turbine shaft that was characterized by a significant clockwise displacement of the reference tube teeth butting against the torque shaft. A 45° torsional shear-fracture of the balancing torque shaft assembly and a shear-fracture of the rear coupling-flange of the torque shaft were observed. This fracturing damage was consistent as a result of the engine and propeller striking and impacting the ground.

2.7 The structural fracturing damage of the front inlet case of the TM and the input drive and rear housings of the RGB is considered consistent with the engine and propeller striking and impacting the ground surroundings. The shear-fracturing of the VDHP and Alternative Current Generator (ACG) drive shafts is consistent with a sudden gear-train stoppage of the RGB that resulted from the engine and propeller striking and impacting the ground.

2.8 The gears and bearings of the reduction and accessory stages of the reduction gearbox had shown gear-train continuity from the input drive to propeller with no evidence of pre-impact distress. Although static rust formation on the surface of the 1st stage reduction gears and bearings observed, occurred from contamination and exposure to the oil wetted parts from environment ground and water that ingress through the structural casing fractures during the aircraft impact and fire extinguishing sequences, and the aircraft salvage and storage conditions.

2.9 The low-pressure (LP) and high-pressure (HP) and power turbine (PT) rotor balancing assemblies of the TM did not show any signs of deterioration or anomalies to the turbines, stators, shafts and main bearings. Although the blade leading edges of the LP and HP centrifugal impellers did display various extents of nicking, gouging and curling damages as characterized as foreign object damage (FOD) that is consistent with ingestion of environmental ground dirt and debris during the aircraft ground impact sequence.

2.10 The primary and secondary air pressure systems of the TM cold and hot sections, and air bleeds showed significant accumulation and contamination of environmental ground dirt and debris ingested during the aircraft ground impact sequence. This indicates that the TM rotor spools were rotating with power during the aircraft ground impact sequence.

2.11 The switching valve of the P2.5/P3 air pressure valve assembly being stuck in the halfway open position due to the foreign debris contaminating the ICC P2.5 plenum is consistent with the ingestion of environmental ground dirt and debris during the aircraft ground impact sequence. This indicates that the HP rotor spool was rotating with power during the aircraft ground impact sequence.

2.12 The evaluation that included inspection and functional testing of the external accessories of the RH engine (TM S/N 115388 & RGB S/N 115316) and of the LH engine S/N AA0045 TSC and EEC referring to the Section 7.0 – P&WC EC&ATS of this report, revealed there were no defects or damage evident that would have prevented normal operation performance and control response of the external accessories prior to the event. The dirt/water contamination and impact damages observed on the accessories are considered secondary damages as results of the aircraft impacting the ground and water used for the post-crash fire extinguishing sequence.

3.0 Conclusions

3.1 The investigation of the RH engine did not reveal any evidences of pre-impact anomalies or defects and/or mechanical deterioration that would have precluded normal operation performance and control response of the engine. All evidences of the investigation showed that all the rotor spools of the RH engine were rotating under power and operating before and during the aircraft impact sequence.

3.2 The investigation of the LH engine S/N AA0045 TSC and EEC revealed no evidence of pre-impact anomalies or defects that would have precluded normal operation performance and control response of these external accessories before the aircraft mishap.

4.0 Remarks

4.1 The raw data of the Flight Deck Recorder (FDR) will be reprocessed accordingly by Transportation Safety Board (TSB) of Canada that was mandated by Nigerian AIB to analyze and produce adequate FDR data graphs for later review when available.

II FACTUAL INFORMATION

1.0 Investigation Participants

The powerplant investigation was performed on April 4th to 9th, 2014 at the Pratt & Whitney Canada (P&WC) Service Investigation Facilities at St. Hubert, Quebec, Canada. The following individuals partially or fully participated in the investigation as representatives of their respective organisations:

Patrick Nwobu, Air Safety Investigator for Accident Investigation Bureau of Nigeria.
Haliru Lawal, Air Safety Investigator for Accident Investigation Bureau of Nigeria.
Marc Hemmings, Pratt & Whitney Canada (P&WC) Service Investigation.
Robert Duma, P&WC Service Investigation.
Claude Beaudry, Air Safety Lead Investigator for P&WC Service Investigation.
Michel Allard, Air Safety Investigator for P&WC Engine Controls & Accessories.

2.0 Right Hand (RH) Engine History

Note that the RH engine log books for records of the maintenance and service elementary works were not received and available with the engine and during the course of the investigation.
The time with cycles of the engine modules are relative because they are based from P&WC Tracking Reliability Aircraft Census (TRAC) of reporting updates from last repair shop visit or from P&WC Field Representative reports.

2.1 <u>PW118 Turbomachine Module (TM) S/N 115388:</u>

Date TM Manufactured: December 1989

Time since New (TSN): 22711

Cycles since New (CSN): 28167

Time since Overhaul (TSO): 9287

Cycles since Overhaul (CSO): 10232

2.2 <u>PW118 Reduction Gearbox (RGB) Module S/N 115316:</u>

Date RGB Manufactured: April 1989

Time since New (TSN): 25421

Cycles since New (CSN): 32423

Time since Overhaul (TSO): 3393

Cycles since Overhaul (CSO): 4165

3.0 Engine Shipping Box Opening & Examination, As-Received

3.1 The large and sealed premade wooden-box as-received was opened in presence of the AIB Nigeria Authorities (photo no. 1). The wooden-box was containing the RH engine that composed of the TM S/N 115388 combined with RGB S/N 115316 was mounted to the severed battered nacelle (photo no's 2 to 8). The nacelle installation was sectioned at the facility outdoor to access and remove the engine. During sectioning of the battered nacelle installation, the exhaust tail pipe (photo no. 9) and the starter generator (photo no. 10) that are considered as airframe parts were noted missing from the engine. The impact-gouged propeller hub (or dome) without blades had remained securely bolted on the engine propeller shaft (photo no. 5) and was de-mated from the propeller shaft (photo no's 11 & 12).

Photo no. 1

Photo no. 2

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Photo no. 3


Photo no. 4


Photo no. 5


photo no. 6

Photo no. 7

Photo no. 8

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Photo no. 9

Photo no. 10

Photo no. 11

Photo no. 12

3.2 The RH engine with several attached airframe components (photo no's 13 to 17) was taken to the Service Investigation Quarantine Area (SIQA) for disassembly investigation.

Photo no. 13

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Photo no. 14 (RH view)


Photo no. 15 (LH view)


Photo no. 16 (Front view)


Photo no. 17 (Rear view)

3.3 Two sealed plastic-bags, identified as EEC Eng #1 and EEC Eng #2, were received stored inside the large wooden-box (photo no. 18) and taken to the SIQA. Each of the bags was opened containing the RH TM S/N 115388 / RGB S/N 115316 Engine Electronic Control (EEC) S/N 87095891 and Torque Signal Conditioner (TSC) S/N RT1293 (photo no's 19 & 20), and the left hand (LH) engine S/N AA0045 EEC S/N 9090010 and TSC S/N MM4896 (photo no's 21 & 22). The torque-shaft characterization plugs were present on the TSC S/N RT1293 (photo no. 20) but the plugs were not present on the TSC S/N MM4896 (photo no. 22). All of the above accessories components were taken by P&WC Engine Controls and Accessories Air Safety Investigator for further evaluation (Refer to Section 7.0 - P&WC Engine Controls and Accessories Technical Services Evaluation (EC&ATS)).

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Photo no. 18

Photo no. 19

Photo no. 20

Photo no. 21

Photo no. 22

3.4 The sectioned engine nacelle installation was disposed and scrapped locally in compliance with the requested authorisation by the AIB Nigeria agency.

4.0 RH Engine "TM S/N 115388 / RGB S/N 115316"; External Examination:

All positional references are in relation to view from aft looking forward. Upstream and downstream references are in relation to gas path flow from the intake to exhaust.

4.1 All the accessories controls considered as airframe components such as the Propeller Control Unit (PCU) S/N 871213, Auxiliary Feathering Pump (AFP) S/N 1386, Variable Delivery Hydraulic Pump (VDHP) S/N MX-467710, Alternative Current Generator (ACG) S/N 594 and the Environment Control System (ECS, or cabin air supply) tubing and control valve linking to the P2.5 check valve and P3 bleed adapter were disassembled from the engine (photo no. 23 to 25), and quarantined.

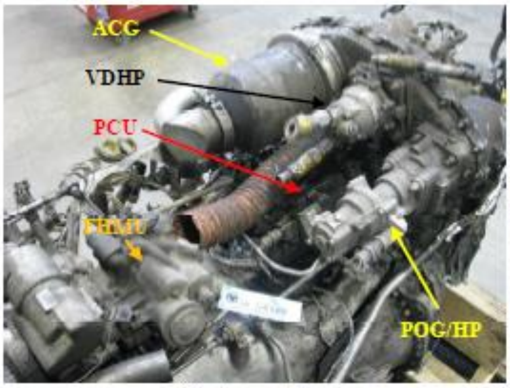

Photo no. 23

Photo no. 24

Photo no. 25

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4.2 On removal, the VDHP and ACG drive shafts were found shear-fractured by overload at their shear neck (photo no's 26 to 29, arrows). The AFP showed impact damages with deformation and partial opening of the unit (photo no. 30). The oil strainer of the AFP was clean (photo no. 31). The other airframe accessories components showed impact gouging damages. On behalf of the AIB Nigeria Authorities request, P&WC shipped the PCU, AFP, VDHP, ACG and the Propeller Hub with the beta tube (rod) to the respective accessories controls suppliers.

Photo no. 26

Photo no. 27

Photo no. 28

Photo no. 29

Photo no. 30

Photo no. 31

4.3 The external of the entire engine including the externals was covered with ground sooty dirt and organic contaminants such as grasses, straws, wood chips, peddles and pieces of red brick-tiles. The P2.5 pneumatic valve of the cabin air supply (ECS, photo no. 25) installed on the inter-stage compressor case (ICC) was contaminated and clogged with a mixture of ground dirt and organic debris (photo no. 32).

Photo no. 32

4.4 The input drive housing and the LH side of the rear housing of the RGB, and the front inlet case (FIC), located in the vicinity of flanges A and B displayed fracturing damages (photo no's 32 to 35) where the RGB module showed a RH offset (pilot view) in relation to the TM axial axis plane (photo no's 16 & 32). The first stage reduction input driveshaft and helical gears and bearings could be seen (being exposed) through openings at the housing fractures (photo no's 34 & 35). The RH torque mounting pad on the rear housing was fractured (photo no. 34, arrow).

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Photo no. 33 (Bottom view)

Photo no. 34 (close-up view)

Photo no. 35 (RH view)

Photo no. 36 (LH view)

4.5 The Propeller Overspeed Governor (POG) S/N 2246800 and the PCU hydraulic pump (HP) S/N 2346157 were intact and securely mounted on the RGB module. Both units with the Propeller speed (Np) sensor S/N 3834 were removed and taken by P&WC Engine Controls & Accessories Investigation Department for evaluation.

4.6 There was no evidence of fire damage noted to the engine externals and casings (photo no's 14 to 17, & 33). The T6 thermocouple bus bars, fire-seals, several oil and air delivery tubes and insulation blankets were dented and bent (photo no's 37 & 38). The T6 thermocouples and harness were intact and securely in place showing no discontinuity with the bus bars. The igniter plugs and ignition harnesses and exciter box were relatively intact and in place showing an impact gouge on the LH igniter cable (photo no. 37). The fuel manifolds and flow divide/dump valve installation were intact and securely in place (photo no's 37 & 38).


Photo no. 37 (LH rear view)


Photo no. 38 (RH rear view)

4.7 The Fuel Heater (FH) S/N WA12214, the Fuel Hydro-mechanical Metering Unit (FHMU) S/N M80641, the Fuel Pump (FP) S/N 2627, the Torque sensor (TQ) S/N 3834 and the HP (NH) and LP (NL) rotor speed sensors were securely in place and intact.

4.8 The FHMU S/N M80641 and the fuel pump S/N 2627 with the torque sensor (TQ) S/N 3834 were removed and taken by P&WC EC&ATS Department for evaluation.

4.9 The RGB (scavenge, photo no's 39 & 40) and TM (main, photo no's 41 & 42) oil filters and chip detectors did not collect ferrous debris, however the scavenge oil filter and its bowl showed dirt and water droplets. The residual oil drained from the TM oil tank was contaminated with water (photo no. 43). The low-pressure (LP), high-pressure (HP) and power turbine (PT) rotor spools could be rotated freely, however there was drive discontinuity between the PT rotor spool and the RGB gear-train. There was drive continuity of the accessory gearbox (AGB) gear-train with the HP rotor spool.

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Photo no. 39

Photo no. 40

Photo no. 41

Photo no. 42

Photo no. 43

5.0 TM S/N 115388; Disassembly Examination

5.1 The RGB was separated from the TM at the flange 'B' requiring no retention disassembly of the balancing torque shaft assembly mated to the RGB input-shaft drive coupling in which the balancing torque shaft assembly composed of the coupling torque shaft and reference tube was found severed in torsion-overload in a 45° plane located at its mid-length (photo no's 44 to 47). A fragment of the coupling shaft assembly was noted resting inside the FIC oil compartment (photo no. 45, arrow). The teeth of the reference tube were permanently displaced in the clockwise direction and butting (or resting) solidly against the coupling torque shaft (side edge of slotted holes, photo no. 48). The 'X' marks of the reference tube in relation with the torque shaft were out of position (offset, photo no. 49). The fractured FIC was removed and showed a second torsional shear-fracture of the coupling shaft at the radius of the shaft/rear coupling (photo no's 50 & 51). The rear coupling was still retained and secured on the PT shaft by the retention bolts and nuts (photo no. 50).

Photo no. 44

Photo no. 45

Views of the fractured RGB input housing and FIC at the mating flange.

Photo no. 46

Photo no. 47

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Photo no. 48

Photo no. 49

Photo no. 50

Photo no. 51

5.2 The turbine exhaust duct (TED) was in a satisfactory condition (photo no. 52). The PT disc balancing assembly (photo no's 53 & 54) that includes the second (2nd) stage PT stator assembly of the PT rotor balancing assembly were in a satisfactory condition. Although, the TED and PT disc assembly were covered and grimed with ground sooty dirt and organic contaminants. The PT shaft (photo no. 55) with the No. 1, 2 and 7 bearings was in a satisfactory condition. A significant accumulation of ground sooty/oily dirt and organic contaminants was noted packed on the circumferential inner wall (photo no. 56, arrow) of the turbine support case (TSC) after removal of the TED and PT pack. Oil wetness and varnishing stains were also noted.

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Photo no. 52 (T/E view)


Photo no. 53 (T/E view)


Photo no. 54 (L/E view)


Photo no. 55

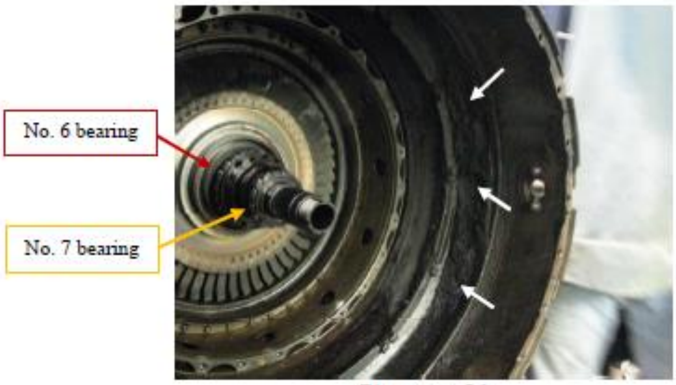

Photo no. 56

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5.3 The first (1st) stage PT stator assembly, baffle, retaining rings and turbine inter-stage case (TIC) were in place, intact and securely retained to the LPT housing by the 26 retention bolts (photo no. 57). The No. 6 & 7 bearings housing assembly and the breather/scavenge and vent transfer tubes were in place, intact and securely retained to the TIC by the 20 retention bolts. The PT1 stator vanes and TIC were intact but grimed with ground sooty dirt and organic contaminants with oil varnishing stains (photo no. 58). The T6 thermocouples and oil transfer tubes were intact and in a satisfactory condition (photo no's 59 & 60).


Photo no. 57

Photo no. 58

Photo no. 59

Photo no. 60

5.4 The inlet wall (cold section gas-path) of the FIC and rear inlet case (RIC) was contaminated and covered with dirt, red-brick tile and organic debris (photo no's 61 & 62). Corrosion was also noted to the casing inlet walls (photo no. 61).

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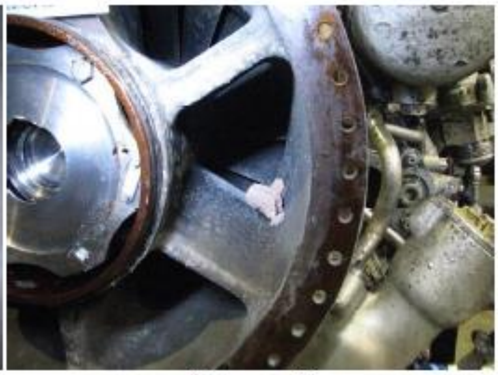

Photo no. 61 Photo no. 62

Views of the engine intake condition.

5.5 The LPT disc assembly, the No. 3 and 6 bearings, the LP shaft of the LP rotor balancing assembly were noted to be in a satisfactory condition (photo no's 63 to 67). The LPT disc assembly was splattered with ground sooty/oily dirt and organic contaminants, and varnished and stained with oil (photo no's 65 & 66). The LP centrifugal impeller being part of the LP rotor balancing assembly showed nicking, gouging and curling damages to the vane leading edges (L/E) from impacts (photo no's 69 to 74). The LP impeller was also grimed and contaminated with ground sooty dirt and organic debris, and a large brick-red tile was found lodged between two vanes (photo no. 74, arrow). The air gas-path wall of the LP diffuser case (Apexes & P2.5/P3 air cavity side, photo no's 67 & 68) and exit ducts were contaminated and splattered with dirt. The LP stator vane-ring (photo no. 75) and shroud segments (photo no. 76) were intact but grimed with dirt.

Photo no. 63 (LPT, T/E view)

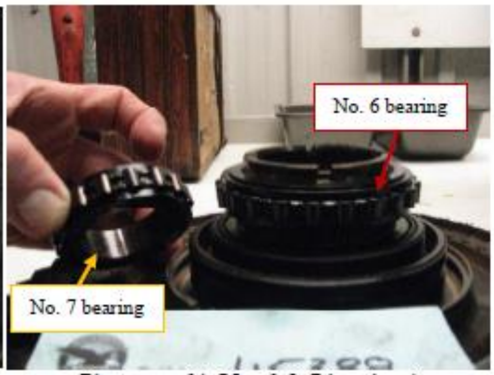

Photo no. 64 (No. 6 & 7 bearings)

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Photo no. 65 (LPT, L/E view)

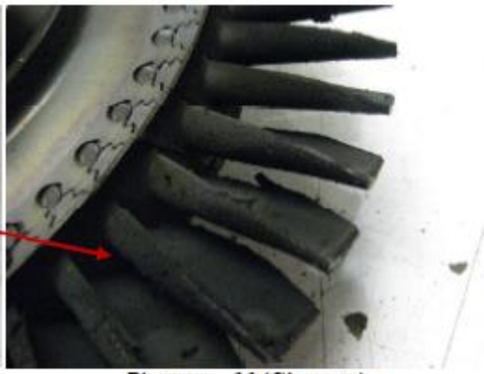
Photo no. 66 (Close-up)

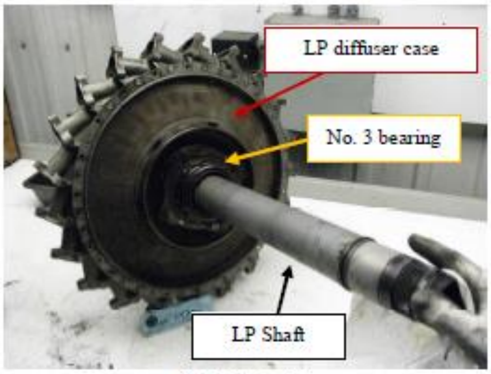

Photo no. 67


Photo no. 68


Photo no. 69 (L/E view)

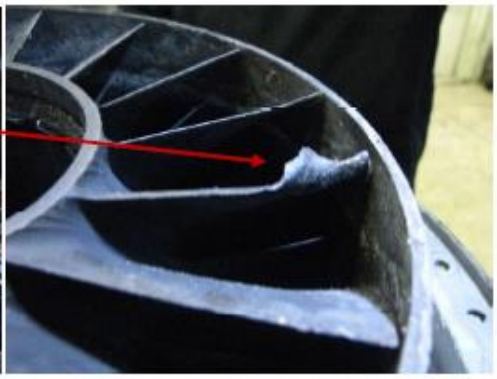
Photo no. 70 (Damaged vane L/E)

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Photo no. 71 (Damaged vane L/E)

Photo no. 72 (Damaged vane L/E)

Alternate views of the impact-damaged vane L/E.

Photo no. 73 (L/E view)

Photo no. 74 (Damaged vane L/E)

Views of the nicked vane L/E's and the lodged tile debris.

Photo no. 75 (T/E view)

Photo no. 76

5.6 De-mated separation of the turbine support case (TSC) from the gas generator case (GGC) at the flange 'K' showed a significant accumulation of ground sooty/oily dirt and organic debris that contaminated, packed and clogged the P3 air cavity (vessel) and pressurizing/cooling-passages formed by the TSC, GGC, the combustion chamber liners and HP stator assembly (photo no's 77 to 93). The internal of the combustion chamber formed by the inner and outer liners was heavily contaminated and covered with ground sooty/oily dirt and organic debris (photo no's 82 & 88). Dark oily varnishing stains were also noted to the aforementioned parts. The P3 air passages and nozzle tips of all the fuel manifolds (FN's) were partially to totally covered and clogged with ground sooty dirt and organic debris in which some growth of fungus formation noted (photo no's 86, 87, 94 to 97). The GGC apexes and diffuser ducts (photo no's 92 & 93) showed impact nicks and foreign dirt/organic contaminants.

Photo no. 77

Photo no. 78

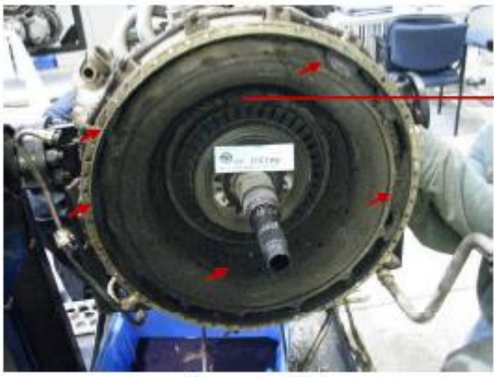

Photo no. 79

Photo no. 80

Photo no. 81

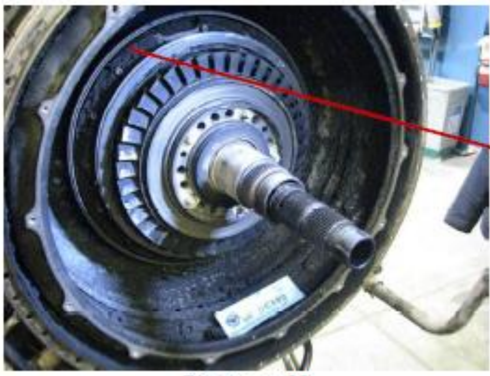

Photo no. 82

Photo no. 83

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Photo no. 84


Photo no. 85

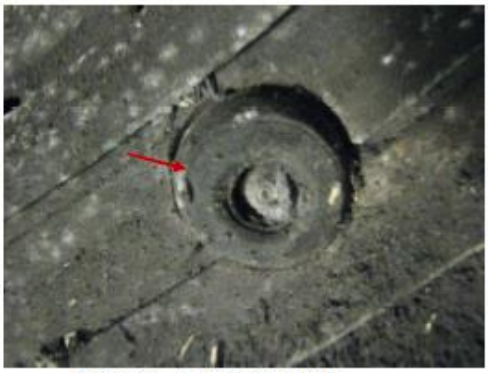
Photo no. 86 (Random FN)


Photo no. 87 (Another random FN)


Photo no. 88 (Inner liner)


Photo no. 89 (Close-up)

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Photo no. 90 (Outer liner)

Photo no. 91 (Close-up)

Photo no. 92

Photo no. 93 (close-up)

Photo no. 94 (Nozzle tip)

Photo no. 95 (P3 air entrance)

Randomly fuel manifold, as representative

This document is subject to the restriction contained on the cover page.
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Photo no. 96 (Nozzle tip) Photo no. 97 (P3 air entrance)
Another randomly fuel manifold, as representative

5.7 The HPT disc assembly (photo no's 82, 98 & 99) and centrifugal impeller (photo no's 100 to 103) with the No. 4 and 5 bearings (photo no's 102 & 103) of the HP rotor balancing assembly were in a satisfactory condition however the L/E of the HP impeller vanes showed various extents of impact nicking and gouging damage. The HP impeller and HPT disc assembly were covered and grimed with ground sooty dirt and organic contaminants, and oil wetness and varnishing stains noted. The upstream wall of the GGC and HP impeller housing forming the P2.5 & P3 air pressure cavity was contaminated and splattered with dirt and organic contaminants (photo no. 100).

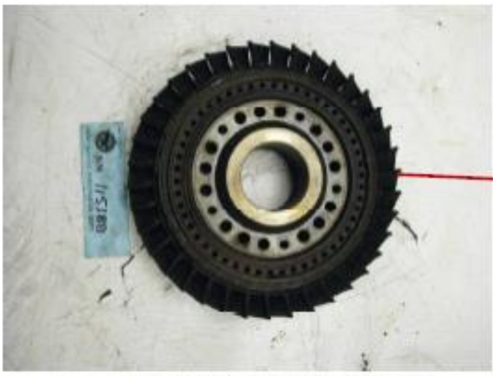


Photo no. 98 (HPT, L/E view) Photo no. 99 (Close-up)

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Photo no. 100 (GGC, L/E view)

Photo no. 101 (Close-up)

Photo no. 102 (HP impeller)

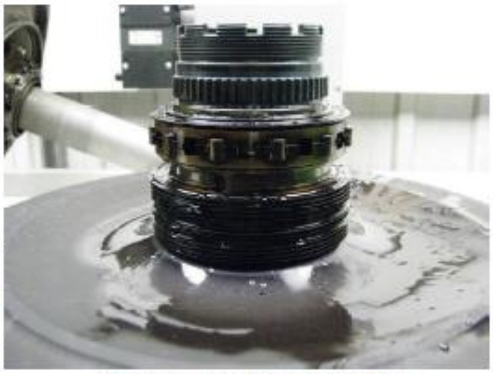

Photo no. 103 (No. 5 bearing)

5.8 The inter-compressor case (ICC) showed that the case upstream/downstream walls forming the P2.5 & P3 air pressure cavity were contaminated and splattered with dirt and organic contaminants (photo no. 104). In addition, a large amount of ground dirt and organic debris was collected and clogging the ICC P2.5 plenum (photo no's 104 & 105) and the inner housing of the P2.5/P3 air pressure valve assembly by keeping (jamming) the switching valve in the halfway open position (photo no's 106 & 107).

Photo no. 104

Photo no. 105

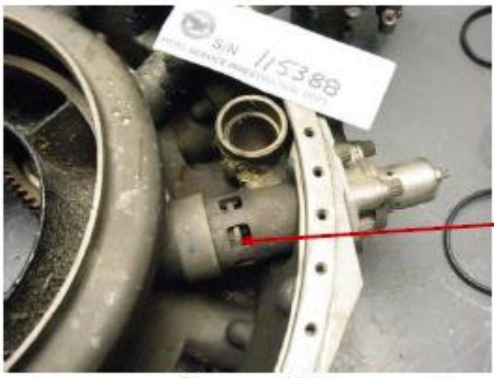

Photo no. 106

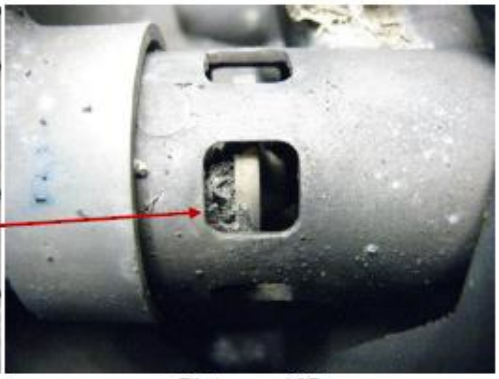

Photo no. 107

5.9 The accessory drive gears, shafts and bearings of the RIC AGB, ICC tower-shaft and HP rotor installations were properly engaged and in a satisfactory condition.

6.0 RGB S/N 115316; Disassembly Examination

6.1 The input-drive housing of the RGB housing set was fractured in large multiple fragments. The oil spray-nozzle transfer tubes of the 1st stage reduction gears and bearings (No. 8 to 12) were fractured. After removal of the housing fragments, the RGB gear-train could be rotated freely. Water, dirt and few brick-red tile fragments were contaminating the oil compartment of the 1st stage reduction gear-train. The lay-shafts and couplings, and the helical gears, input shaft and bearings composing the 1st stage reduction gear-train of the RGB were intact but the gears and bearings were dry and displayed stationary surface corrosion characterised by the rusty-orange and dark oxide discolorations. Refer to photo no's 108 to 124.

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Photo no. 108


Photo no. 109

Downstream views of the fractured 1st stage reduction input-drive housing, and the installation of the 1st stage reduction gear-train.


Photo no. 110


Photo no. 111

Alternate views of the fractured 1st stage reduction input-drive housing and oil transfer tubes, and rusted bearing outer races.


Photo no. 112 (No. 8) Photo no. 113 (RH No. 11)
Close-up views of the rusted condition of two of 1st stage bearing outer races.


Photo no. 114 (LH side) Photo no. 115 (RH side)
Alternate views of the condition of the 1st stage reduction gear-train, and the fractured RGB rear housing on the RH side.

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Photo no. 116
Close-up view of the rusted input drive gear with mating helical gears.

Photo no. 117

Photo no. 118

Views of the 1st stage reduction gear-train, and the input drive shaft and coupling.

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Photo no. 119 Photo no. 120
Views of the LH and RH 1st stage reduction helical gears /lay shafts/bearings assemblies.

Photo no. 121 (LH side) Photo no. 122 (RH side)
Alternate views of the condition of the LH and RH layshaft vernier-couplings.

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Photo no. 123 Photo no. 124

Alternate views of the contaminated RGB rear-housing compartment of the installation of the 1st stage reduction gear-train and bearings.

6.2 The propeller shaft, the bull and pinion gears and bearings (No. 15 to 19) of the 2nd stage reduction gear-train were in a satisfactory condition and could be manually rotated freely. Refer to photo no's 125 to 129.

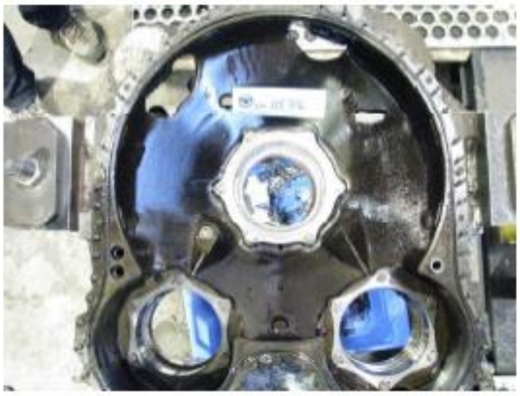

Photo no. 125
View of the RGB rear-housing compartment of the 2nd stage reduction gear-train and bearings installation.

Photo no. 126

Photo no. 127

Alternate views of the general condition of the installation of the 2nd stage reduction gear-train, bearings and front housing.

Photo no. 128 (No. 18 bearing)

Photo no. 129 (No. 19 bearing)

6.3 The accessory drive gears and bearings of the RGB module were in a satisfactory condition. Refer to photo no's 130 to 133.

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Photo no. 130 (RGB) Photo no. 131 (Gears)
Views of the RGB accessory drive gear-train.

Photo no. 132 (RGB) Photo no. 133 (Cover)
Views of the RGB accessory drive gear bearings.

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7.0 P&WC EC&ATS Evaluation

7.1 <u>LH Engine S/N AA0045 Torque Signal Conditioner (TSC) P/N 3118356-03, S/N MM4896:</u>

Visual inspection of the TSC in a dirty condition showed the lower RH mounting flange was bent. The Torque (TQ) trim plugs were missing. The electrical connectors (J6, J7, J10 & J11) were dirty but the connector contact pins were intact. The connectors were cleaned before the unit being bench-tested. The unit functional testing in accordance with calibration test-requirements showed all of the test points were successfully completed. The back cover was removed and the inspection of the electronic board displayed minor corrosion build-up on the filter support (arrow). Refer to photo no's 134 & 135.


Photo no. 134

Photo no. 135

7.2 <u>LH Engine S/N AA0045 Engine Electronic Control (EEC) P/N 3118356-03, S/N 9090010:</u>

Visual inspection of the EEC in dirty condition showed the lock-wiring devices on the straight and elbow fittings of the transducer ports and the tube nut were found sectioned. The transducer ports were free and not obstructed from contaminants. The retention nut on the elbow fitting was found loose. The electrical connector was contaminated with sand and organic debris however no damage was observed to connector contact pins. The electrical connector was cleaned and the functional test that was performed in compliance with calibration testing requirements revealed all of the test points being successfully completed. The back plate was removed and the electronic boards were inspected revealing no damage or abnormal condition noted.
Refer to photo no's 136 to 138.

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Photo no. 136

Photo no. 137

Photo no. 138

7.3 RH Engine S/N's 115388/115316 TSC P/N 3118356-03, S/N RT1293:

Visual examination of the TSC in dirty condition showed that its back-cover displayed minor denting and gouging damage. TQ trim plugs being rusted were attached to the unit with the presence of sealed locking-wires. The top electrical connectors (J6 & J7) were contaminated with dirt. TQ trim plugs (J10 and J11) were removed and inspected revealing the connectors to be clean and intact. Verification of the jumper position on the J10 trim plug (torque gain) was 7-10 identified as a Class 5 and the J11 trim plug (torque offset) was 3-6 as a Class 35 matching the scribed trim data on the engine reference data plate.
All connectors were cleaned and the functional test that was performed in accordance with calibration test-requirements revealing all of the test points met the calibration limits except for a minor calibration deviation of the torque indication at low propeller speed (Np) that would cause an approximately 0.005% low torque indication readout at idle speed only.
The back-cover was removed and inspection of the electronic board did display corrosion build-up (photo no. 141, yellow arrow) on the filter support bracket.
Refer to photo no's 139 to 141.

Photo no. 139

Photo no. 140

Photo no. 141

7.4 RH Engine S/N's 115388/115316 EEC P/N 3038922, S/N 87095891

Visual inspection of the EEC in dirty condition showed the lock-wiring devices on the straight and elbow fittings of the transducer ports and the tube nut were found sectioned. The transducer ports were not obstructed and free of contaminants. The retention nut on the elbow fitting was found loose. The back cover showed multiple impact scratches. Electrical connector was dirty and the contact pins were intact.
The electrical connector was cleaned and the functional test as-is, in compliance with calibration testing-requirements, was aborted due to a faulty reversion light circuit being permanently "ON". The unit back plate was then removed. The inspection of the housing (internal) and electronic boards displayed a significant amount of water droplets and corrosion on the housing entire perimeter and in the area of the pressure transducers. A cracked solder joint was observed at the 28 volts Electro-Magnetic Interference (EMI) filter. A wire from the total pressure transducer (Pto) was found not fully seated in the electrical connector. The unit was dried, removing moisture, and the damaged solder joint and the unseated wire were repaired. Further testing of the EEC showed the unit satisfactory responding to all the commanded test points performed. The only anomaly detected was a slow air leak within the static air pressure transducer (Pso) generating a minor signal drift.
Refer to photo no's 142 to 145.

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Photo no. 142

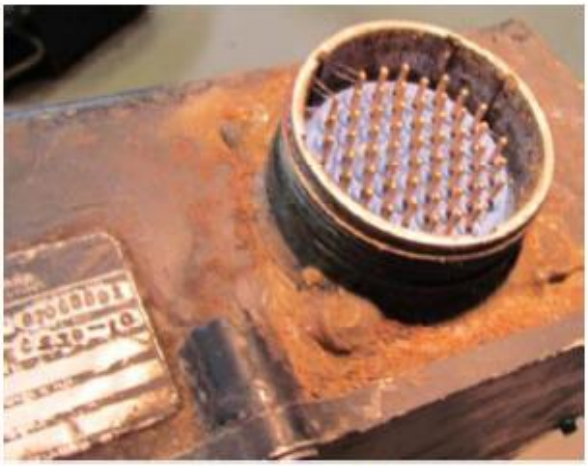

Photo no. 143

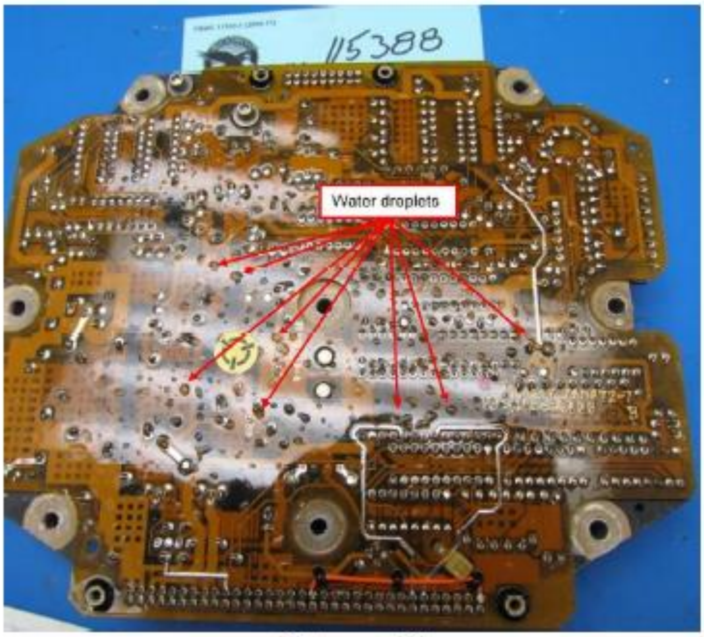

Photo no. 144

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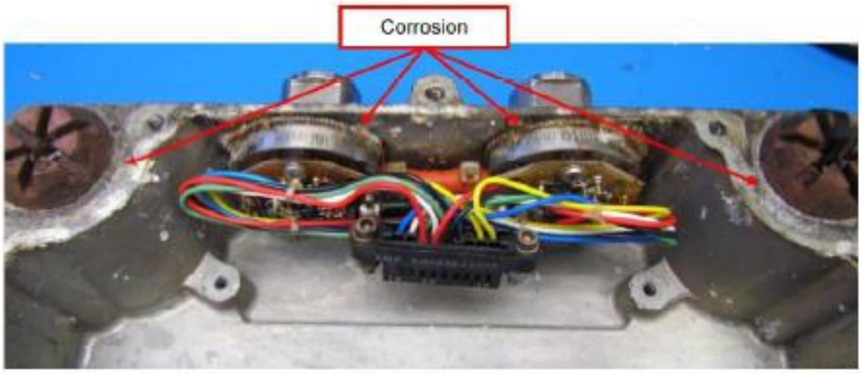

Photo no. 145

7.5 RH Engine S/N's 115388/115316 Hydro-Mechanical Fuel Control (HMFC) P/N 3117033-04, S/N M80641:

The HMFC was covered with dirt and the electrical connector was clean with no damage observed to contact pins (photo no. 146). All the lock-wires and seals were present and secured properly. Manual operation of the condition and power levers did not reveal any side play or abnormal resistance. All fuel and air ports were free of contamination. The result of the HMFC functionally test as-is in accordance with the supplier Component Maintenance Manual (CMM) calibration testing specifications showed some of the test points being out of calibration, however the test confirmed that the unit could supply the required fuel flow for take-off (TO).

Photo no. 146

7.6 RH Engine S/N's 115388/115316 Fuel Pump P/N 3117095-01, S/N 2627:

The pump was dirty and all lock-wires were present and secured properly (photo no. 147). No damage or abnormal condition was observed to the pump housing and drive shaft. An unapproved sealant tape was present at the pump mounting flange. The packing was chipped at a location (photo no. 148). The fuel filter was removed and found to be clean. The residual fuel collected from the fuel filter cavity showed no contaminants or water content. The fuel pump functionally test performed in accordance with the supplier CMM testing instructions revealed all the test points meeting requirements.

Photo no. 147

Photo no. 148

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7.7 RH Engine S/N's 115388/115316 Torque (TQ) Sensor P/N 3111978-01, S/N 551 & Propeller Speed (Np) Sensor P/N 3033515, S/N 3834

The TQ and Np sensors were covered with dirt and oil. The electrical connector including the contact pins of both sensors was dry and intact. The functionally test preformed on both sensors in accordance with the appropriate CMM test instructions met requirements.

7.8 RH Engine S/N's 115388/115316 Propeller Overspeed Governor P/N 3039336, S/N 2246800 & Hydraulic Pump P/N 3034719, S/N 2346157:

Both units as an assembly were covered with dirt and soot (photo no. 149). Air and oil ports were clean. The drive shaft could be manually rotated and showed no side play or abnormal resistance. The units were sent to the supplier for further investigation revealing that the inspection and testing of the Propeller Overspeed Governor and Hydraulic Pump did not reveal or confirm any malfunction issues.

Photo no. 149

8.0 Reference Listing

P&WC Accessories Accident Investigation Report RFA No. 14GA00001A/B/C

APPENDIX B: Field Return Failure Analysis: Auxilliary Propeller Feathering Pump

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FIELD RETURN FAILURE ANALYSIS: AUXILLIARY PROPELLOR FEATHERING PUMP

CUSTOMERS: NTSB, HAMILTON SUNDSTRAND & EMBRAER

DOCUMENT 40-1107

AEROCONTROLEX P/N: 4122-009005
HAMILTON SUNSTRAND P/N: 783687-3

Prepared & Approved By: _

Director of Engineering

REVISION PAGE

REV	DESCRIPTION	DATE	CHECKED	APPROVED
-	ER 22799	11 Dec 2015	BF	CLB

Field Return Test Report Document No. 40-1107 Revision -	AERO CONTROLEX 4223 Monticello Blvd. South Euclid, OH 44121 Page 3 of 29

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LIST OF APPENDECIES

1.0 Introduction

1.1 Scope

This report documents the tear-down, inspection and testing of an auxiliary propeller feathering pump (ACX P/N 4122-009005, S/N 1386) which was installed on an Embraer 120 aircraft which was involved in an accident. Figure 1 below shows the data plate. The serial number is not fully legible in the as-received photo, but was reconstructed from the folded bits of the data plate that had come loose during shipping.

Table 1: Unit Information

ACX P/N	Hamilton Sundstrand P/N	S/N	Last Overhaul
4122-009005	783687-3	1386	Sept. 1996

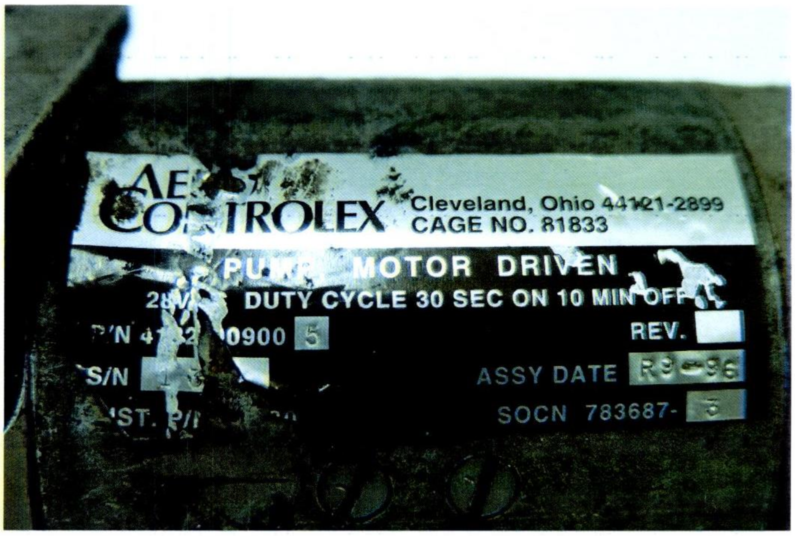

Figure 1
Pump Data Plate

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1.2 Background

1.2.1 On October 3rd, 2013 an Embraer 120 registered as 5N-BJY crashed during takeoff from Murtala Muhammed International Airport in Lagos, Nigeria.

1.2.2 Pratt Whitney Canada shipped the auxiliary propeller feathering pump to AeroControlex on April 22, 2014. The paperwork with the pump stated that it was installed on Pratt Whitney model PW118 engine with TM S/N 115388 and RGB S/N 115316. It is not known by ACX if this was the port or starboard engine on the aircraft.

1.2.3 Per instructions on the shipping paperwork, officials from the Nigerian Accident Investigation Bureau (AIB) were called upon receipt of the pump on April 29, 2014. Contact was also made with James Shinkoff at Hamilton Sundstrand. Dennis Jones with the NTSB contacted ACX on July 20, 2014 and established that all communication on this matter should be handled through the NTSB. The NTSB coordinated all communications to the AIB and the Brazilian authorities.

1.2.4 The NTSB assigned Rick Greenlief from the Cleveland FAA MIDO to witness the testing and teardown.

1.2.5 The auxiliary pump was evaluated on April 15, 2015 with the following people present:

- C irector of Engineering for AeroControlex
- F viation Safety Inspector for the FAA, Cleveland MIDO Office
- Ca mbraer Air Safety – External Investigations.

2.0 Field Return Failure Investigation Results

The auxiliary pump was evaluated on April 15, 2015. The evaluation started with a visual inspection and electrical checks and was followed by partial disassembly. Then the pump sub-assembly was then tested per the ATP. After ATP both the pump and motor were fully disassembled for component inspection.

2.1 Visual External Inspection

2.1.1 Exterior examination of the unit showed that the electric motor housing had separated rendering the unit inoperable. See red arrows in Figures 2 through 4. The damage appears to have occurred when the aircraft impacted the ground. The pump subassembly itself appeared to be intact. The mounting flange, hydraulic transfer tubes and electrical connector were all in good condition. All fasteners and lock-wire were present and did not appear to have been disturbed. See Figures 2 through 5.

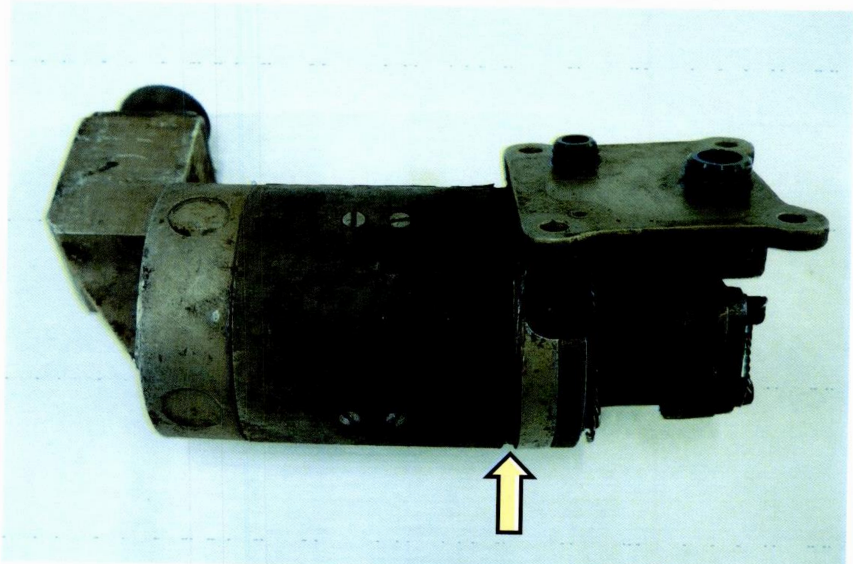


Figure 2
Pump and Motor Assembly, Back

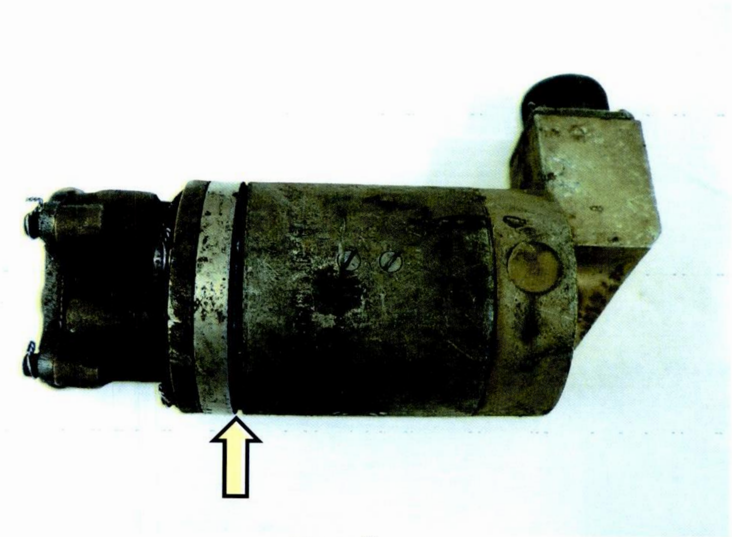


Figure 3
Pump and Motor Assembly, Front

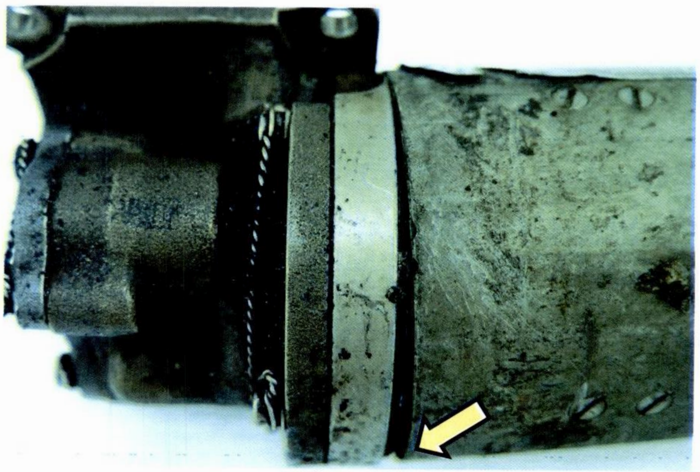


Figure 4
Close-up of Motor Housing Separation

2.1.2 After a thorough visual examination and photographs were taken, the hydraulic pump sub-assembly was separated from the electric motor for further examination. This was done so the pump sub-assembly could be tested separately. The photos below show the interface where the pump sub-assembly mates to the electric motor. The mounting bolts and shaft were undamaged.

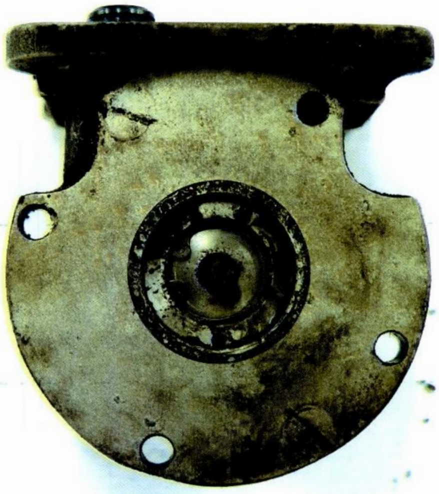


Figure 6
Pump Subassembly, Motor Mounting Surface

2.1.3 The pictures below are of the mounting surface of the electric motor and the shaft coupling that connects the motor to the pump sub-assembly. The mounting holes and coupler were undamaged. Figure 8 shows that the slotted countersunk screws that hold the motor housing together had not rotated despite the damage to the housing.

Figure 7
Electric Motor with Gasket and Coupler Installed

Figure 8
Electric Motor without Gasket or Coupler

2.2 Electrical Checks

2.2.1 After the electric motor was removed from the pump sub-assembly, a multi-meter was used to check for electrical shorting to case. No shorts were found from the pins to the housing. The stator fields and rotor windings were also checked for continuity. All field and rotor windings were intact, so electrically the motor would have been operable prior to impact.

2.3 Pump Sub-Assembly ATP

2.3.1 After being separated from the electric motor, the hydraulic pump was tested in accordance with the CMM and production ATP. Figure 9 shows the pump installed on the ATP test stand.

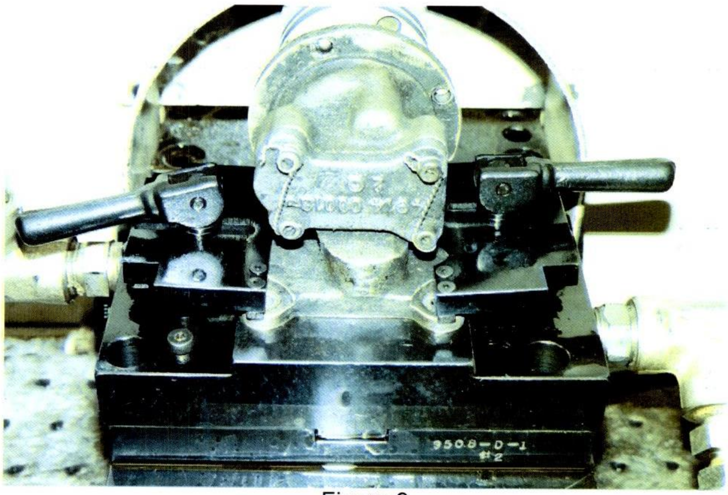


Figure 9
Pump Sub-assembly on Test Stand

2.3.2 Figure 10 shows the digital readouts on the test stand for pressures, flow and RPM. Figure 11 shows the unit with the test data sheet.

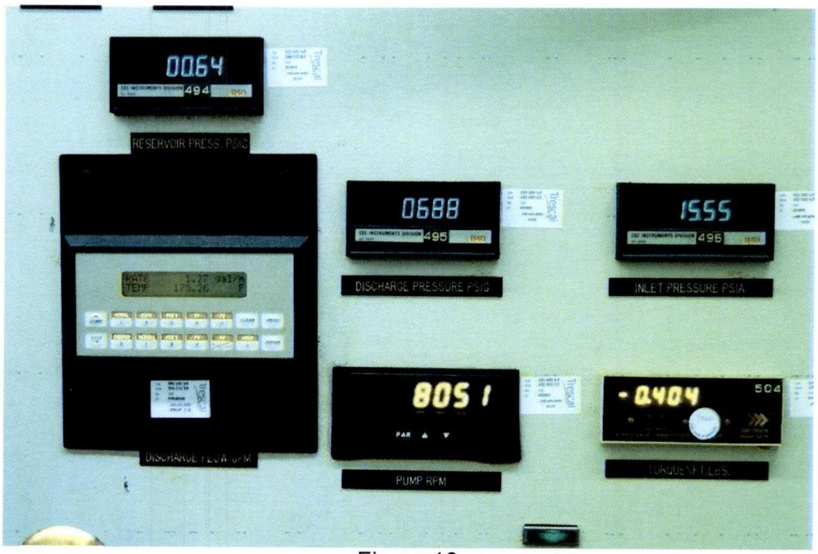
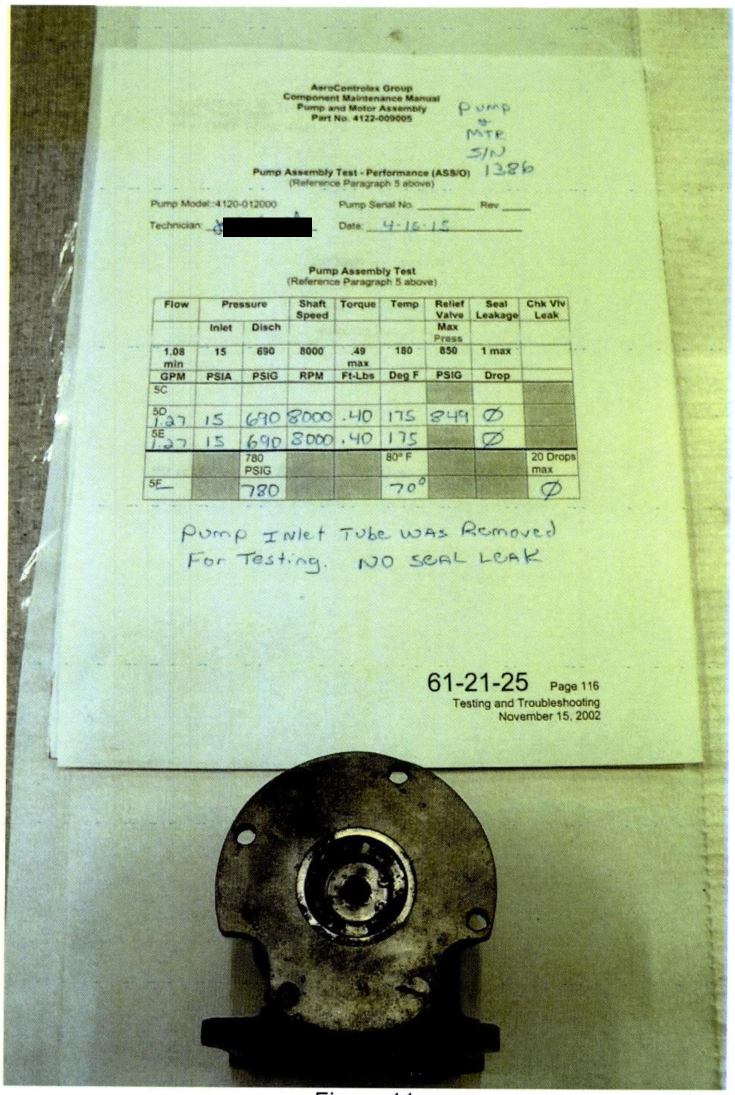


Figure 10
Test Stand Readouts



AeroControlex Group
Component Maintenance Manual
Pump and Motor Assembly
Part No. 4122-009005

Pump + MTR S/N 1386

Pump Assembly Test - Performance (ASS/O)
(Reference Paragraph 5 above)

Pump Model: 4120-012000 Pump Serial No. ________ Rev ____
Technician: [redacted] Date: 4-16-15

Pump Assembly Test
(Reference Paragraph 5 above)

Flow	Pressure		Shaft Speed	Torque	Temp	Relief Valve	Seal Leakage	Chk Vlv Leak
	Inlet	Disch				Max Press		
1.08 min	15	690	8000	.49 max	180	850	1 max	
GPM	PSIA	PSIG	RPM	Ft-Lbs	Deg F	PSIG	Drop	
5C								
5D 1.27	15	690	8000	.40	175	849	Ø	
5E 1.27	15	690	8000	.40	175		Ø	
		780 PSIG			80° F			20 Drops max
5E		780			70°			Ø

Pump Inlet Tube was Removed For Testing. NO SEAL LEAK

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November 15, 2002

Figure 11
Pump Sub-Assembly and Test Data Sheet

2.3.3 The pump sub-assembly met all test requirements. There were also no leaks found during testing. The function of the relief valve and check valve were also tested and met the requirements.

2.3.4 Overall it was also observed that this pump had very little wear on the gears, bearings and housing indicating that the unit did not have a lot of running hours on it.

2.3.5 It should be noted that the pump inlet screen had to be removed from the unit to allow for testing as is stated on the test sheet in Appendix B. This was done just so the unit would fit on the test rig because during normal production testing the screen is not on the pump.

2.4 Disassembly & Component Inspection

2.4.1 Motor

2.4.1.1 The motor was disassembled as shown in Figures 12 through 19. Disassembly showed that the impact had caused the following damage: one of the two clamping screw helicoils pulled out of the housing, the tip of the output shaft was slightly bent, and the output shaft bearing was slightly cocked in its bore. See red arrows in figures 13, 14 and 15.

2.4.1.2 Disassembly also showed that the carbon brushes and all internal wiring were intact. See figures 13 and 16 through 19. All bearings were also intact and free to rotate. There was no evidence of any internal rubbing or binding between the rotor or stator. See Figures 16 through 19.

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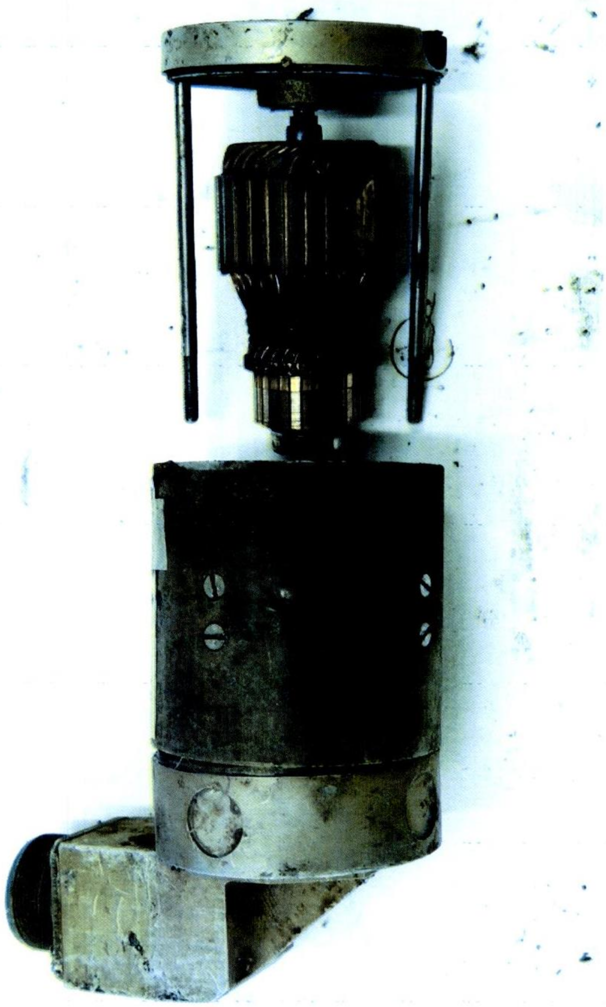

Figure 12
Motor with Rotor Removed

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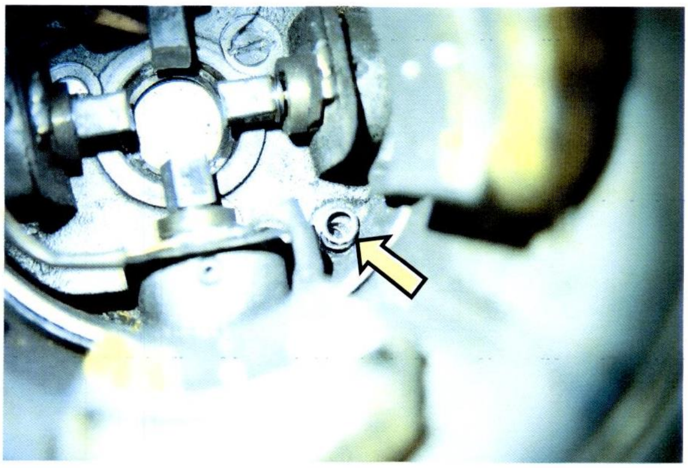

Figure 13
Motor Housing Clamping Helicoil Pulled Out

Figure 14
Motor Output Shaft Tip Bent

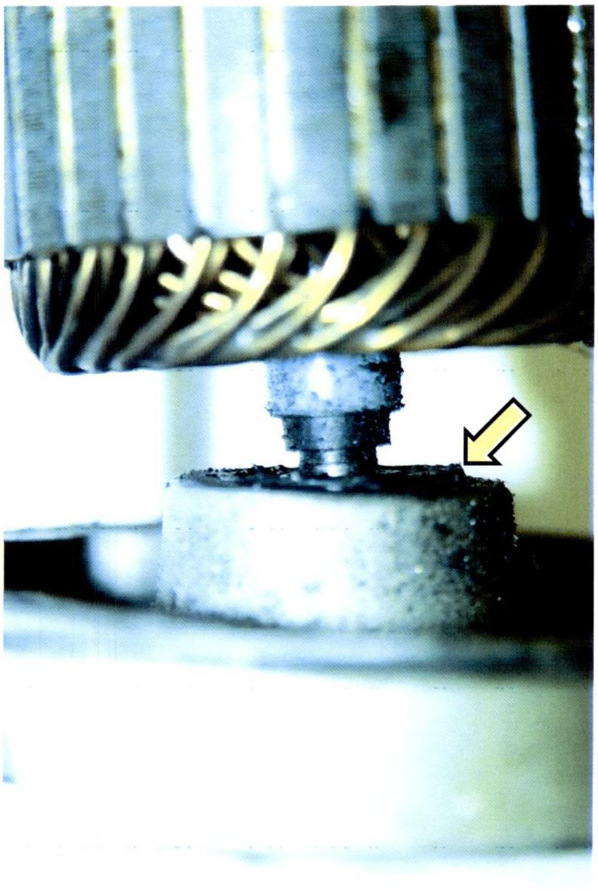

Figure 15
Motor Bearing Cocked at Output Shaft

2.4.1.3 Lastly there was some light surface corrosion seen on two of the field magnets and matching marks on the rotor. See red arrows in figures 16 and 19. These most likely occurred after the accident when the aircraft was hosed down with water to extinguish the fire. Since the motor housing was bent and the rotor was now touching the stator. Water wicked between them where they were touching. That is most likely why the surface corrosion occurred. It should also be noted that light corrosion like this would not prevent the motor from working.

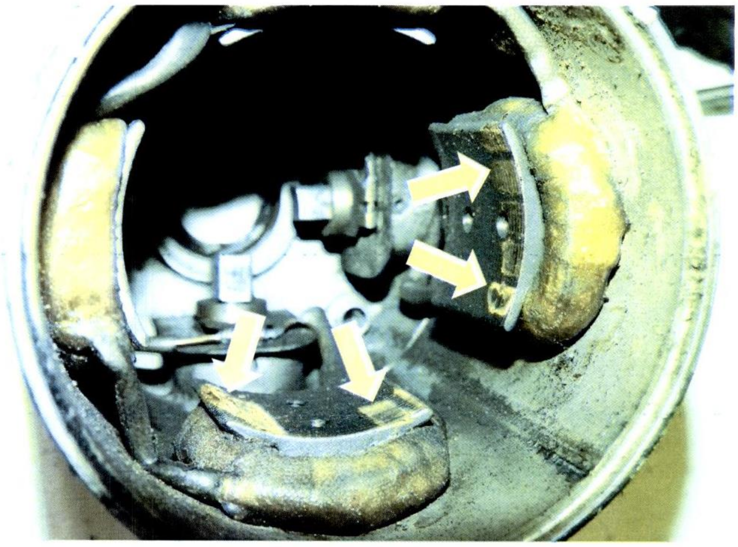

Figure 16
Motor Stator Magnets and Brushes View #1

Field Return Test Report Document No. 40-1107 Revision -	AERO CONTROLEX 4223 Monticello Blvd. South Euclid, OH 44121 Page 20 of 29

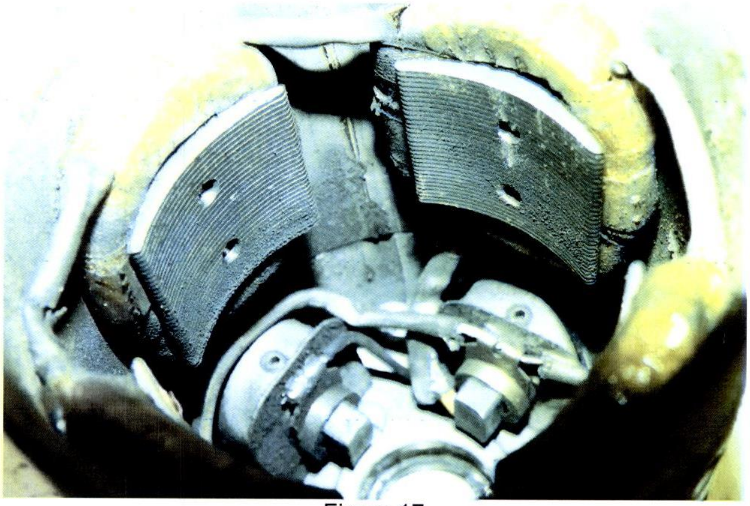

Figure 17
Motor Stator Magnets and Brushes View #2

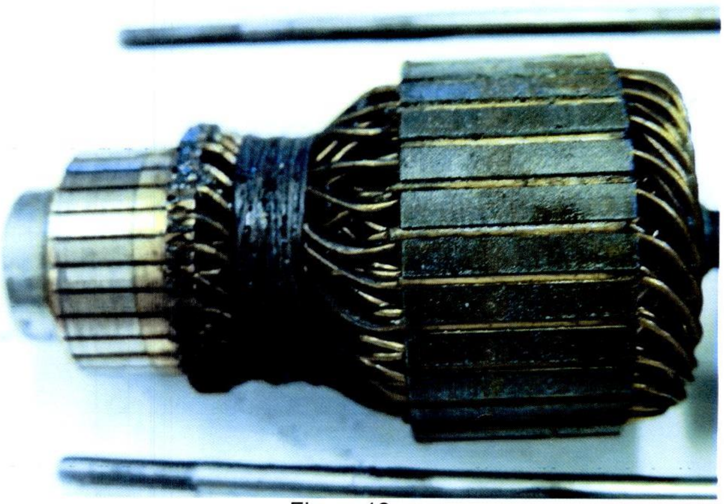

Figure 18
Motor Rotor View #1

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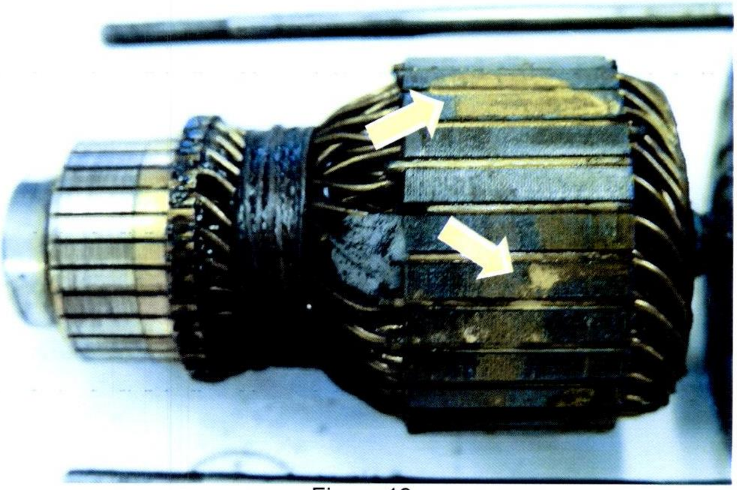

Figure 19
Motor Rotor View #2

2.4.1.4 Based on the findings of this teardown, we believe this motor was fully functional prior to the damage caused by impact.

2.4.2 Pump Sub-Assembly

2.4.2.1 After being fully tested, the pump sub-assembly was torn down and inspected. Figures 20 through 22 show the pump sub-assembly, disassembly and components.

Figure 20
Pump Sub-assembly with Cover Removed

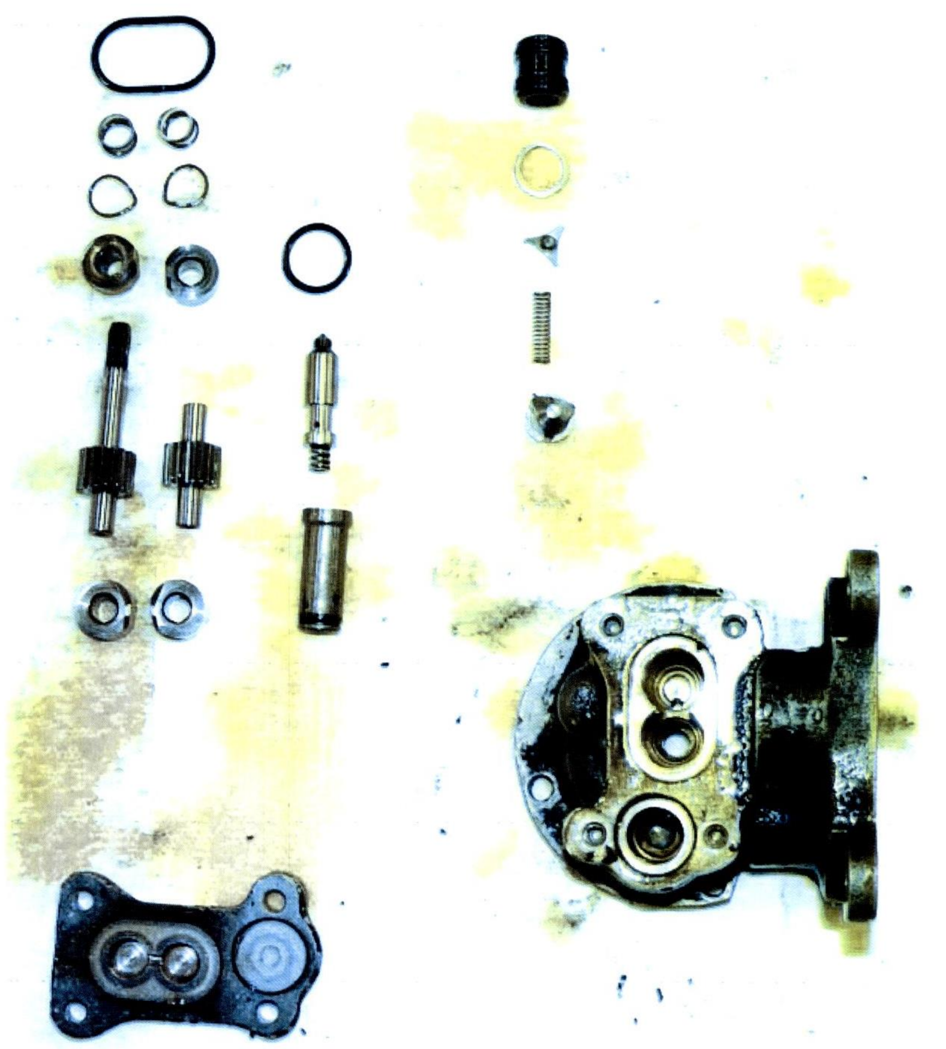

Figure 21
Pump Components: Housing, Cover, Bearings, Gears, Seals and Valves

2.4.2.2 Figure 22 shows the pump inlet screen which was removed for testing. It was clean and undamaged.

Figure 22
Pump Inlet Screen

2.4.2.1 As is shown by the figures and testing, no anomalies were found with any parts of the pump sub-assembly. The pump sub-assembly was in working order at the time of the accident.

3.0 Conclusion

3.1 The initial visual inspection of the unit showed that the motor was damaged. This damage most likely occurred during impact. The pump sub-assembly was intact.

3.2 The pump sub-assembly was separated from the motor. The pump sub-assembly passed a production ATP. After testing, a detailed teardown and inspection of the pump sub-assembly's components showed no anomalies. The pump sub-assembly was in good working order at the time of the accident.

3.3 The motor was torn down and the only issues found with the components were related to the impact damage. The impact caused the damage to the motor which caused it to bind. It is our professional opinion that the condition of the parts shows that the motor was in good working order prior to the accident and subsequent impact damage.

3.4 AeroControlex has thoroughly evaluated, tested and inspected the returned pump assembly P/N 4122-009005, S/N 1386. The evidence gathered shows that the unit was in good working order prior to the accident on October 3rd, 2013.

Appendix A: 4122-009005 Drawing

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Appendix B: CMM Test Data Sheet

AeroControlex Group
Component Maintenance Manual
Pump and Motor Assembly
Part No. 4122-009005

Pump & MTR S/N 1386

Pump Assembly Test - Performance (ASS/O)
(Reference Paragraph 5 above)

Pump Model 4120-012000   Pump Serial No. ________ Rev ____

Technician: [illegible]   Date: 4-15-12

Pump Assembly Test
(Reference Paragraph 5 above)

Flow	Pressure Inlet	Pressure Disch	Shaft Speed	Torque	Temp	Relief Valve Max Press	Seal Leakage	Chk Vlv Leak
1.08 min	15	630	8000	.40 max	180	850	1 max	
GPM	PSIA	PSIG	RPM	Ft-Lbs	Deg F	PSIG	Drop	
5C								
5D 1.27	15	690	8000	.40	175	849	Ø	
5C 1.27	15	690	8000	.40	175		Ø	
		780 PSIG			90° F			20 Drops max
5E		780			70°			Ø

Pump inlet tube was removed for testing. No seal leak.

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Testing and Troubleshooting
November 15, 2002

APPENDIX C
Hydraulic Pump Evaluation

EATON Service Engineering Report

SERVICE ENGINEERING REPORT NO: NTSB2015MAR12_MX467710	Date: 2015 Mar 12

Report Title	Hydraulic Pump Evaluation
Pump Information	
Model Number	PV3-022-29
Part Number	P/N 570796
Serial Number	MX-467710
Engine Model Number	PW118
Engine Serial Number	TM S/N 115388 / RGB S/N 115316
Customer	NTSB / AIB Nigeria
Aircraft Type	EMB-120
Call No.	C182829
Report Number	SERNTSB2015MAR12_MX-467710
Date	March 12, 2015
Prepared by	Jo Product Support Manager

Eaton Aerospace
Fuel & Motion Control System Division
5353 Highland Drive
Jackson, MS 39205-3449
Tel: (601) 987-3446
Fax: (601) 987-4717

EATON Service Engineering Report

SERVICE ENGINEERING REPORT NO: NTSB2015MAR12_MX467710	Date: 2015 Mar 12

1.0 PURPOSE AND SCOPE

The purpose of this report is to detail the test results from a factory performance test of a model PV3-022-29 Hydraulic Pump (P/N 570796), S/N MX-467710. The pump was removed from a PW118 engine, removed from an EMB-120 aircraft following an incident in Nigeria.

Representatives from FAA witnessing the test and evaluation were:

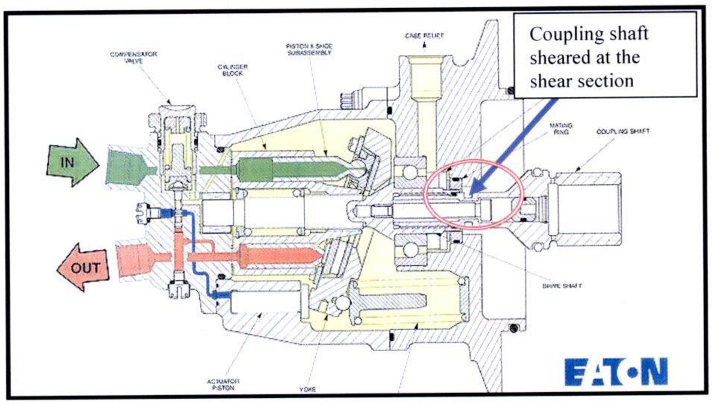
F - Flight Safety District Office

2.0 FINDINGS

2.1 Visual Inspection Findings

The pump was visually inspected for damage. A summary of the damage is provided in the narrative in Photo 1. Additional supporting data is provided in photo's 2 – 4.

Photo 1 - Flow Schematic of Typical Hydraulic Pump



The pump was an older pump (originally shipped ~ February 1988) and had some normal residual wear and tear. The coupling shaft was sheared when received and a portion of the coupling shaft was retained in the pump drive shaft. The pump has some additional fittings in the ports from the aircraft installation. All the ports were and open exposed to the environment. We took the following actions:

1) The additional fittings were removed and retained
2) The portion of coupling shaft was removed and retained
3) The turning torque was checked for low torque and smooth operation
    a. There was smooth operations and low turning torque (~ 2 IN LB)
4) Based on the turning torque and general condition of the pump it was decided to functionally test the pump per the production TP – 8084. (See Table 1 for results)
    a. The pump passed all performance tests with the exception of a slight decrease in zero flow pressure (2981 psi verses requirement of 3000 psi).

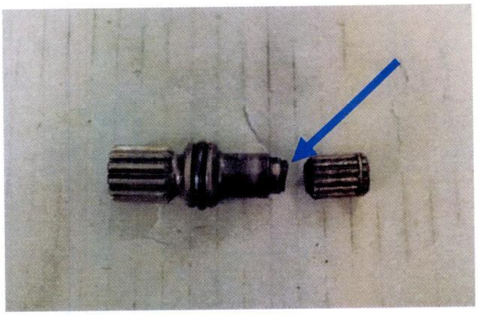
EATON Service Engineering Report

SERVICE ENGINEERING REPORT NO: NTSB2015MAR12_MX467710	Date: 2015 Mar 12

2.1.1 Coupling Shaft Sheared - Portion Retained in Pump

Photo 2 provides visual evidence of damage to the coupling shaft in the receipt condition. The smaller portion was captured and retained in the pump drive shaft by the retaining ring. The shaft failed in the shear section as it was designed to do.

Photo 2 – Coupling Shaft Sheared



The coupling shaft was sheared when received. A metallurgical evaluation indicates the shaft failed due to torsional overload. There appears to have been very limited run time following the failure.

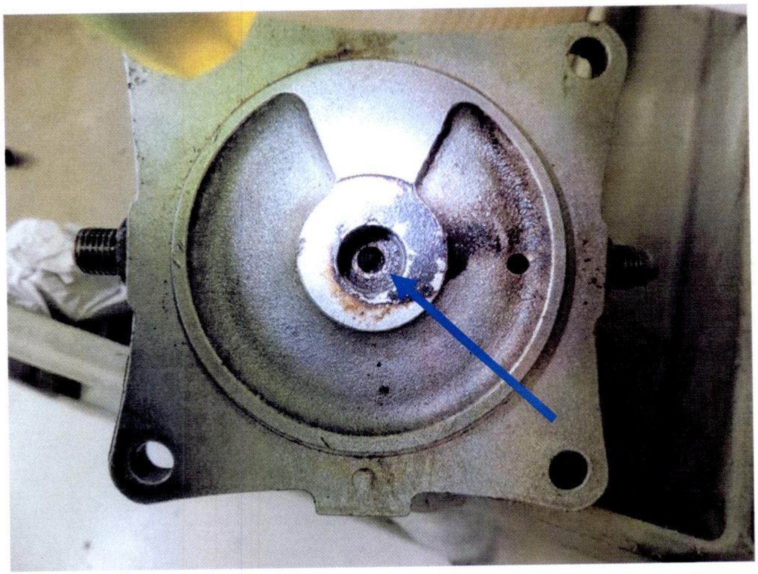
The reason for the failure is not known as the pump performance was within the limits expected. The failure may have occurred during the incident or following the incident while trying to remove the coupling shaft.

EATON Service Engineering Report

SERVICE ENGINEERING REPORT NO: NTSB2015MAR12_MX467710	Date: 2015 Mar 12

Photo 3 provides visual evidence of portion of the coupling retained in the pump drive shaft. This portion was removed to allow mounting of the pump to the test stand.

Photo 3 – Coupling Shaft



The coupling shaft failed in a torsional load. There appears to be some residual grease from the coupling shaft installation.

EATON Service Engineering Report

SERVICE ENGINEERING REPORT NO: NTSB2015MAR12_MX467710	Date: 2015 Mar 12

2.2 Pump Testing – Pump tested on Production Test Stand 33

Photo 4 provides visual evidence of pump on the test stand. The pump was tested per the production TP – 8084.

Photo 4

The test stand setup for testing the pump is as used for production hardware. The test results are presented in Table 1.

EATON Service Engineering Report

SERVICE ENGINEERING REPORT NO: NTSB2015MAR12_MX467710	Date: 2015 Mar 12

2.2.1 Pump Testing Results

Table 1 provides a summary of the test requirements and the test results.

Performance Test Results

Test Performed	TP Limits	Actual Test Data
External Leakage	None other than slight wetting insufficient to form a drop	__X__ Accept
Shaft seal	5 drops in 10 minutes Max	_0_ Drops / 10 minutes
Pressure @ zero flow (7630 rpm)	3000 + 50, - 0	2981 psig
Full flow @ 2850 psi (7630 rpm)	5.0 gpm Min	5.4 gpm
Stability - Sudden changes in delivery	No continued or persistent hunting of yoke for position	__X_ Accept
Pressure Creep - 5 min @ cut-off (7630 rpm)	+/- 25 psi maximum from pressure at time of cut-off	2988 psi (cut-off) 2987 psi (after 5 minutes) 1 psi pressure change
Case Leakage – 7630 rpm - Cut-off leakage - Full flow leakage	Maximum leakages: .40 gpm .26 gpm	Case leakages .183 gpm .192 gpm
Speed Scan (30 to 60 seconds) - 7630 to 3000 to 7630 rpm	No persistent oscillation lasting more than (1) second	__X__ Accept
Friction Hand Torque - Breakaway - Turning	Maximum limits - 14 lbf-in - 9 lbf-in	Measured values: _7_ lbf-in _3_ lbf-in
The pump operation was smooth/quiet with low pulsations and no unusual noises.		

AIB Nigeria Page | 6

EATON Service Engineering Report

SERVICE ENGINEERING REPORT NO: NTSB2015MAR12_MX467710	Date: 2015 Mar 12

3.0 CONCLUSION

The performance of the pump was very good for a pump that had come from a service environment. The pump ran very quiet and all the performance parameters were achieved with the exception of a small deviation in the zero flow pressure (2981 psi verses 3000 psi). There was no external leakage (parting line or shaft seal) and the full flow was .4 gpm greater than the 5.0 gpm requirement.

Based on the performance of the pump there is no evidence that the pump had an impact on the incident.

APPENDIX D

NIGERIAN CIVIL AVIATION AUTHORITY

CERTIFICATE OF AIRWORTHINESS

NO. 1239

NATIONALITY AND REGISTRATION MARKS	MANUFACTURER AND MANUFACTURER'S DESIGNATION OF AIRCRAFT	AIRCRAFT SERIAL No
5N - BJY	EMBRAER EMB-120ER	120174
		Date of Manufacture
		FEB., 1990

CATEGORY: TRANSPORT

This Certificate of Airworthiness is issued pursuant to the Convention on International Civil Aviation dated 7th December, 1944 and the Civil Aviation Act, 2006 and the Order and Regulations issued thereunder, in respect of the above-mentioned aircraft, which is considered to be airworthy when equipped, maintained and operated in accordance with the foregoing and the pertinent operating limitations. A Flight Manual forms part of this Certificate.

Designation: AVIATION SAFETY INSPECTOR

Signature: ______ for the Nigerian Civil Aviation Authority

Date of First Issue: 12TH JUNE, 2007.

This certificate is valid for the period(s) indicated below	Signature, Official Stamp and Date
From 26TH JULY, 2013 to 22ND OCTOBER, 2013.	25 NCAA AIR 26/07/2013

NOTES:

1. No entries or endorsements may be made on this Certificate except in the manner and by the persons authorized for the purpose
2. If this Certificate is lost, the issuing authority should be informed at once, the Certificate Number being quoted.
3. Any person finding this certificate should forward it immediately to the issuing authority
4. This Certificate must be displayed aboard the aircraft.

Form: AC-AWS 002

APPENDIX E

OFFICE OF THE CHIEF MEDICAL EXAMINER

c/o Department of Pathology & Forensic Medicine,
Lagos State University College of Medicine, Ikeja, Lagos, Nigeria.
Tel: 0809 269 8443, 0806 043 2255. E-mail: cmelagosstate@gmal.com

The Commissioner/CEO,

Accident Investigation Bureau,

Murtala Mohammed Int'l Airport,

Ikeja,

Lagos.

April 29, 2015

Dear Sir,

Report on the Associated Airline Crash of 3rd October 2013.

I Prof. John Oladapo Obafunwa, The Chief Medical Examiner, received a phone call at 1019 hours on the 3rd of October, 2013 from Dr Haggai of NCAA inviting the Forensic Pathology team to come to the scene of a plane crash disaster around Muritala Mohammed International Airport, Ikeja, Lagos. The team comprising of Prof J.O. Obafunwa, Dr. D.A. Sanni and Mrs. T.A. Ogunsola (TOS Funerals) left the Department of Pathology and Forensic Medicine, LASUTH at 1023 hours for the site of the disaster.

The team arrived at the crash site at 1048 hours and was escorted into the area by Dr Haggai. The site is the Aviation fuel tank farm, close to the Lagos International Airport. The wreckage of the plane was seen but the bodies of the victims and the survivors had already been evacuated to LASUTH. The plane was alleged to belong to Associated Aviation. The Associated Airline plane, which had the serial number 5N-BJY, was said to have had 20 passengers which included members of Dr Olusegun Agagu's family, friends, pall bearers working for MIC caskets, crew members and the body of Late Dr.

1

Olusegun Agagu on board. The latter was in a coffin in the cargo compartment of the plane. The chartered flight was said to have taken off from the airport en route to Ondo state for a burial ceremony but crashed shortly after take-off. Various agencies which include LASEMA, NEMA, NCAA, AIB, FAAN, Fire service, Police, and Air force staff were present, either working to put out the fire, pulling parts of the wreckage to safety or restricting on-lookers/sympathizers while trying to ensure law and order. Part of the wrecked plane (rear end) was cut open with the use of heavy duty equipment to expose where the Late Dr Agagu's coffin was placed. The coffin was recovered at 1220 hours and transferred to the NAF Medical Centre Mortuary. The team left the crash site at 1235 hours.

The team arrived at the Nigerian Air force Base Medical Centre at Ikeja, and had a short meeting with the Commandant, Air Commodore Shinkafi in his office at 1250 hours. The Late Dr Agagu's coffin with his body lying within was sighted at 1300 hours at the hospital's morgue. One of the bodies of the victims of the crash was also present in the morgue. A survivor who was being treated was seen at the hospital's emergency unit. It was agreed that the body at the morgue should be transferred to LASUTH for proper forensic evaluation. The team left the Air force base at 1316 hours for LASUTH.

The team arrived at the LASUTH Surgical Emergency Department at 1331 hours. Five survivors seen in the emergency room were being resuscitated while two other dead victims were yet to be transferred to the morgue. The team later arrived at the morgue at 1345hours where ten bodies were sighted, some of which were burnt beyond recognition. The other deceased from NAF Medical centre was received in the morgue at 1440 hours.

Altogether 13 deaths were recorded on the first day of the event and one survivor later died two days later. Two other survivors that were admitted into LASUTH also died despite rigorous specialist intervention on the 5th of October, 2013. The remaining survivor was eventually transferred to the Burns Unit in General Hospital Gbagada for specialist treatment. This patient later died on 7th of November, 2013.

Prior to the commencement of post mortem examination, three pathology teams, radiology and odontology teams were constituted with the Chief

Medical Examiner being the overall supervisor. Dr. Faduyile F.A. Dr. Soyemi S.S. and I constituted the pathology teams and we were assisted by resident doctors in the pathology department. Professor Awosanya G.O. and Dr.Ogunbanjo V. each headed the radiology and odontology teams respectively. Thus each body prior to post mortem examination had total body radiological examination and dental charting.

Full post mortem examination was commenced on 4th of October, 2013 and by the close of work on 5th of October we had performed autopsy on 14 bodies. During the examination, adequate attention was paid to the clothing and other personal items recovered on the bodies. Photographs were systemically taken and burnt into CDs. A chunk of iliopsoas and a segment of the ribs were retained in each case for the purpose of DNA analysis. In addition, samples of the vitreous fluid, venous blood and urine were also retained for toxicological analysis. As part of routine investigation during post mortem examination, samples of all the organs were also taken, fixed in formalin and sent for histological examination.

We again performed a post mortem examination on one of the victims that died in the hospital 4 days after the crash. Unfortunately, the victim with severe burns died in Gbagada General Hospital on 7th November, 2013 and the autopsy was performed on the same day. This brings to 16 the total number of deceased individuals who died in the crash and had post mortem examinations.

There were 15 males and only one female. The distribution of the various causes of deaths is as follows:

1.	Multiple injuries following airplane crash.	9
2.	Asphyxia following inhalational injury and CO poison.	3
3.	Severe craniocerebral injuries following airplane crash.	3
4.	Severe cerebral oedema following airplane crash.	1
	Total	16

The 16 bodies were all identified using a combination of DNA and the post mortem examination. They included the pilot, co- pilot and flight engineer. These bodies had since been released to their respective families. The death certificates have also been collected by their next of kins.

3

The results of the toxicology in the victims was essentially negative for common drugs of abuse except for the presence of post mortem alcohol production in blood and urine in one victim and same in only blood in another victim.

[redacted]

Chief Medical Examiner

4