

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

September 14, 2021

Attachment 4 –Eaton Hydraulic Engine Driven Pumps Investigation Report

POWERPLANTS

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LEVEL 1 INVESTIGATION REPORT

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Report No	L1/Bdh/19/011	Customer	NTSB / Airbus
Part No	3022053-001	Operator	Delta Airlines
Model Code	PV3-300-EA2A	Customer P.O	1009365615
Description	Engine Driven Pump (EDP)	Eaton Call I.D	T233101
Serial No	G0710126	Date Received	28 th Dec 2018
Admin Owner	Rikki Heke	Date of Manufacture	1 st Qtr 2007
Ref Docs/CMM	29-10-56	Date of Repair	N/A

APPLICATION INFORMATION

Application	A330	Unit Location	ENG #2 Yellow System
Aircraft Registration No	N806NW	Date Removed	Not stated
Time Since New (hours)	45318:30	Cycles Since New	6043
Time Since Repair (hours)	39486:36	Cycles Since Repair	5134

REASON FOR RETURN

To support an investigation into a Delta A330 engine fire event and to determine if the EDP contributed to the ensuing fire.

SUMMARY

There was no evidence to suggest an EDP malfunction prior to the engine fire event.

The metallurgical analysis confirmed that the EDP structural components were subjected to a temperature approaching 1112 °F (600 °C). This was sufficient to re-temper the steel valve block, aluminium housing and adaptor block leading to the structural failure and separation of the valve block and rotating group sections.

Based on the findings in this report it is concluded that the EDP was not a contributing factor to the engine fire event, the EDP failure was entirely due to exposure to an intense fire.

Warranty Verdict	Expired	X	Denied		Accept		Partial Acceptance	
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Report Prepared by	Approved by	Approved by	Warranty Reviewed by	Quality Approval
Steve Badenoch	Stuart Tucker	Jason Hands	Helen Dawson	Ian Dickson
Product Support Manager Date 28 Aug 2019	Director Product Support Date 6 Sep 2019	Project Engineer Date 29 Aug 2019	Contract Manager Date 6 Sep 2019	Quality Manager Date 30 Aug 2019

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1 INTRODUCTION

The subject of this investigation is Eaton EDP P/N 3022053-001, S/N G0710126 removed from a Delta Airlines A330 aircraft N806NW. This aircraft was subject to a fire event on a Pratt & Whitney (PW) engine shortly after take-off from Atlanta. The fire lasted for approximately 25 minutes and was extinguished on the ground following a safe landing.

During this period the EDP was exposed to an intense fire and suffered thermal damage to the extent that the aluminium housing had melted. The EDP was returned in two major sections.

The EDP remains were returned to Eaton's Bedhampton facility for investigation.

The main objectives of the investigation are given below:

- What was the possibility of the EDP contributing to the fire?
- If possible determine the heat exposure time and temperatures reached.

A second EDP S/N G0941963 from the same engine but located on the Green system was intact and removed for investigation. This EDP was delivered to Bedhampton later, where an on receipt inspection was performed on 6th June and found to have black sludge contamination (thermally stressed fluid) in the hydraulic ports. Under the direction of the AAIB investigator Eaton was advised that no further work was needed on this EDP.

The main investigation was performed on the 10th and 11th April, the table below lists all the representatives who participated in the investigation.

Attendee Name	Company	Title
Andrew Cox	Air Accidents Investigation Branch	Inspector of Air Accidents
Jean-Francoise Berthier	Bureau d'Enquetes et d'Analyses	Safety Investigator
Lars Hoffmann	Airbus	Hydraulic System Expert
Robert Schwinn	Airbus	Hydraulic System Engineer
Guillaume Verger	Airbus	Product Safety
Taylor Smith	Delta Airlines	Air Safety Investigator
Rodney Simon	Delta Airlines	Principal Engineer, Component Engineering
Steve Badenoch	Eaton	Product Support Manager
Leigh Hardiman	Eaton	Senior Product Support Engineer
Steve Riley	Eaton	Chief Engineer

Table 1 : List of Investigation Participants

This report details the observations, findings and results of a metallurgical investigation. The report chronology follows the sequence of the investigation events.

The following abbreviations apply throughout this report:

AAIB : Air Accidents Investigation Branch

BEA : Bureau d'Enquetes et d'Analyses

CT : Computerised Tomography

EDP : Engine Driven Pump

FSOV : Fire Shut Off Valve
NTSB : National Transportation Safety Board

2 PACKAGING

The EDP was delivered and booked in on 28th Dec 2018 in two separate Delta TechOps cardboard boxes. There was no external identification on the boxes stating that the contents were subject to an investigation or must not be opened. The boxes were opened and the paperwork inside the box clearly stated it must not be worked on without authorization from NTSB. Both boxes were retrieved from stores, quarantined and remained untouched until the arrival of the AAIB representation (AAIB was acting as an agent of the NTSB).



Photo No 1: EDP Packaging Boxes

3 COMPUTERISED TOMOGRAPHY SCAN – ROTATING GROUP SECTION

As reported the EDP was returned in two sections, the bottom part of the EDP contained the rotating group and the top part contained the valve block, compensator, adaptor block and wafer plate. For clarification the two sections are identified as the rotating group section and valve block section herein. It was agreed in advance to perform a Computerised Tomography (CT) scan on the rotating group section in the as received condition. The objective of the CT scan was to determine the integrity of the rotating group, provide a record of the condition and position of individual components prior to disassembly and inspection.

The rotating group and valve block sections were unpacked in the presence of Andrew Cox (AAIB representative) on the 9th April 2019. It was noted that the polythene bags containing the sections were split open.



The material was set up on the CT scanner and allowed to run overnight.



- The quality and resolution of the live images observed was considered sufficient to examine the rotating group section.
- The images confirmed the rotating group assembly was intact with no component damage or visible abnormalities evident.

Both sections were unpacked and placed on a workbench for a visual inspection. The EDP Serial No G0710126 was confirmed by Delta Airlines.



Photo No 4 EDP Sections as Received

5.1 Valve Block Section

The following observations were made:

- All surfaces were blackened and covered with soot.
- A section of material from the case drain port was missing.
- The remains of a hose end connection (non EDP part) was attached to the hydraulic suction port.
- The wafer plate fell off its locating pins during normal handling of the material.
- External fasteners and steel inserts were exposed where surrounding aluminum material from the adaptor block had melted, some of the screws were bent.
- The Electrical Depressurising Valve (EDV) aircraft electrical connector was still fitted, only partial remains of the electrical lead was left.
- The compensator wire locking was still attached.
- A section of the fractured aluminum housing was attached to the adaptor block.
- A section of aluminum adaptor block material appeared to have melted and folded over.



Photo No 5A and 5B: Valve Block External Surfaces

5.2 Rotating Group Section

The following observations were made:

- External surfaces were burnt, blackened and covered with soot/thermally stressed hydraulic fluid.
- The mounting flange cavity and one side of the housing was stained with a yellow tinge, possibly due to burning or fire extinguishant residue.
- The internal components were in a similar condition, unidentified sand coloured grains were adhered to the internal components.
- It was noted that a large section of the aluminum housing was missing, the actuator piston and identity plate was also missing.
- The coupling shaft had sheared, the EDP spline end was retained in the driveshaft.
- The cylinder block was sitting abnormally high on the driveshaft.
- The impeller washer and screw were still retained and screwed onto the driveshaft. This was considered unusual as the impeller is screwed onto the shaft and retained by the washer but remained in the valve block section.
- The rotating group appeared to be intact with no visual evidence of mechanical failure.
- There was no visual evidence of metallic contamination within the EDP indicative of running surface degradation.



Photo No 6A, 6B and 6C: External Surfaces Housing and Mounting Flange Cavity

6 TEARDOWN INSPECTION-

This section presents the visual findings of the sequential strip and internal condition of the EDP components.

In advance of the teardown inspection it was agreed to take multiple samples of the substances adhered to component surfaces. Sampling equipment included carbon tape and small sampling bottles.

6.1 Rotating Group Section

Prior to disassembly the following actions were completed:

A record of the cylinder block position relative to the drive shaft was made by scribing a mark on the drive shaft in line with the lift limiter shim as shown in the photograph below.



Photo No 7 : Alignment Mark Cylinder Block to Driveshaft

The alignment of the cylinder block to the housing was recorded by etching lines on the external surfaces.



Photo No 8 : Alignment Mark Cylinder Block to Housing

The housing screw positions were etched onto the housing, upon removal all screws were placed in a separate bag labelled with their corresponding number.



Photo No 9 : Housing Screw Positions

6.1.1 Housing

The housing screw torque values were evaluated, correct assembly torque limits are 290 to 300 lbf.in. The evaluation confirmed a reduction in torque where movement was detected with a calibrated torque wrench set at 100 lbf.in.

Upon removal inspection found the entire internal surface area was blackened, a build up of sludge (possibly thermally stressed fluid) had collected on one side adjacent to the pintle bearing.

There was no evidence of internal mechanical damage.



Photo No 10A and 10B : Housing

6.1.2 Cylinder Block

The nine cylinder block bores and pistons were each engraved 1 to 9 prior to disassembly to identify and maintain a record of the piston to bore positions.

The drive shaft to cylinder block alignment was also marked up to record the cylinder block spline to drive shaft spline alignment.

The screws were removed from the piston shoe retainer plate allowing removal of the cylinder block complete with the piston and shoe subassemblies, piston shoe retainer plate and piston dial plate.



Photo No 11 : Cylinder Block, Pistons, Piston Shoe Retainer Plate and Dial Plate

The following observations were made:

- All components were coated with thermally stressed fluid.
- All nine pistons were seized in their respective cylinder block bores, no attempt was made to remove any piston and shoe subassembly.
- The piston shoes were scuffed and scratched but maintained a healthy layer of bronze with no evidence of abnormal / excessive wear.
- There was no visual evidence of piston shoe retainer plate mechanical deformation. The bronze bearing surface on the plate was intact and appeared to be in a good condition with no evidence of abnormal loading or excessive wear.



Photo No 12 : Piston Shoes

6.2 Valve Block Section

The valve block and adaptor block were an abnormally tight fit and it was necessary to prise the components apart. Upon separation the following observations were made:

The impeller was retained in the valve block and had fragmented into three major pieces. The fracture surfaces were fibrous in appearance. All surfaces were covered in a thick coating of thermally stressed fluid. Multiple impeller blades were bent and surface scoring was evident where running contact was made with the adaptor block.



Photo No 13A : Impeller Retained in Adaptor Block

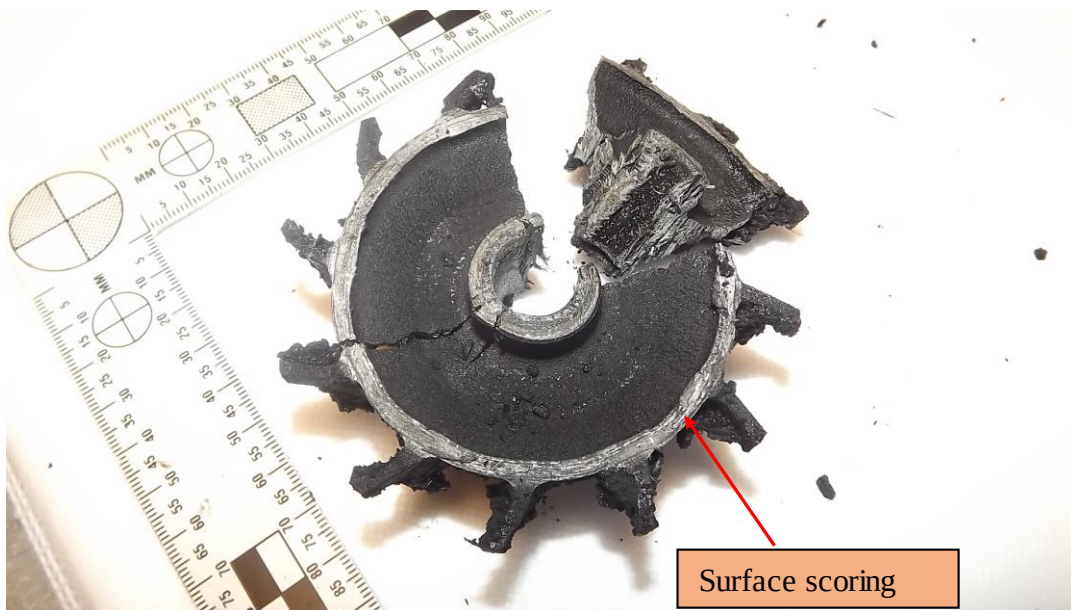
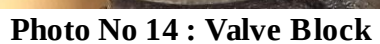


Photo No 13B : Impeller Fracture and Scoring

The valve block and adaptor block were heavily contaminated with thick deposits of thermally stressed fluid.

The blocking valve was jammed with thermally stressed fluid in the open position.



Examination of the fracture surfaces and microstructure of the aluminum impeller, housing and adaptor block revealed that they had all been heated to temperatures that had produced a change in the microstructure, weakening the grain boundaries, lowering the tensile and shear strength of these components.

Bending loads from the mass of the valve block end of the pump created a tensile load through the top face of the mounted housing. When the materials became weak enough from heat exposure this inherent loading was enough to fracture the housing and pull mounting lugs apart.

Evidence suggests that following failure of the pump housing, shear loading of the bolt and washer pulling through the impeller caused the failure of the impeller and also fractured the tips off the vanes. During this failure the torque on the coupling shaft would have increased.

Examination of the fracture surfaces and microstructure of the coupling shaft revealed that it had failed at the 'shear' point due to an excessive torque loading, i.e. failed in torsion; this area of the shaft was not weakened by the fire.

Metallurgical examination of the steel valve block revealed that the fire had re-tempered the steel. The new temper was consistent with heating to approximately 1100°F (593 °C).

Physical evidence and heat treatment tests strongly suggest that the housing was exposed to temperatures very close to 1112 °F (600°C). It was noted that the lower side of the housing, nearest to

the mounting flange, was subjected to a reduced heating close to 932°F (500 °C), otherwise the evidence suggests that the fire heating was even over the whole pump.

8 CONCLUSIONS

There was no evidence to suggest an EDP malfunction prior to the engine fire event.

The metallurgical analysis confirmed that the EDP structural components were subjected to a temperature approaching 1112°F (600°C.) This was sufficient to re-temper the steel valve block, aluminium housing and adaptor block leading to the structural failure and separation of the valve block and rotating group sections.

Based on the findings in this report it is concluded that the EDP was not a contributing factor to the engine fire event, the EDP failure was entirely due to exposure to an intense fire.

APPENDIX A: IMAGES FROM CT SCAN

