Havarikommissionen
Accident Investigation Board Denmark

**FINAL REPORT**

| | | | |
|---|---|---|---|
| **HCLJ510-2013-200** | **Serious incident** | | |
| Aircraft: | Partenavia P68 Observer | Registration: | OY-SUR |
| Engines: | 2 Lycoming IO-360-A1B6 | Flight: | Other, VFR |
| Crew: | 1 – No injuries | Passengers: | None |
| Place: | 5 nm north of ODIN VOR Fyn | Date and time: | 24.4.2013 at 06:56 UTC |

All times in this report are UTC.

**Table of contents**

The Aviation Unit of the Accident Investigation Board Denmark (AIB DK) was notified of the serious incident by the Area Control Centre at Copenhagen Airport, Kastrup on 24.4.2013 at 07:20 UTC.

The European Aviation Safety Agency (EASA), the Italian Agenzia Nazionale per la Sicurezza del Volo (ANSV), the European Commission (EC) and the Danish Transport Authority were notified on 25.4.2013.

## FACTUAL INFORMATION

### History of the flight

The serious incident flight was a ferry flight from Copenhagen Airport, Roskilde (EKRK) with Billund Airport (EKBI) as planned destination.

After approx. 20 minutes of flight, the pilot cross fed both engines for one minute.
Then he selected the right engine to the right fuel tank and the left engine to the left fuel tank.
Shortly hereafter the pilot selected the right engine to the left fuel tank to balance fuel.

After approx. 30 minutes of flight, the pilot observed an abnormal mechanical noise from the left engine.

The pilot reduced the left engine power to idle to protect the engine against further damage.
He decided it was most appropriate to keep the engine running if power was needed later on the flight.

The right engine throttle was set to maximum power (MP) and the fuel supply was selected right tank to right engine.
Both electrical fuel pumps were selected on.

The pilot informed Copenhagen Information about the engine problem and that the intention was to divert to Odense Airport (EKOD) situated 15 nm southwest of the present position.

En-route to EKOD, the pilot noticed some intermittent loss of power from the right engine.
Furthermore, the pilot observed that the right engine cylinder temperature was abnormally high but still below the red line.

The pilot was uncertain on the right engine performance, called Odense AFIS, declared an emergency and selected the transponder code to 7700.

The left engine was running at idle power, when the aircraft was landed at EKOD without any further incidents.

The serious incident took place in daylight under visual meteorological conditions (VMC).

**Personnel information**

The pilot – male – 33 years old was in possession of a valid Commercial Pilot License (CPL) issued by the Danish Transport Authority on 15.6.2011.

The pilot's medical class 1 was valid until 25.9.2013.

| Flying hours: | Last 24 hrs. | Last 90 days | Total |
|---|---|---|---|
| This aircraft type: | 1 | 108 | 300 |
| All types: | 1 | 108 | 716 |

**Aircraft information**

General

The twin engine high wing aircraft was manufactured in Italy 1981 by Partenavia Costruzioni Aero SpA as P68 Observer S/N 246-04-OB.

The Airworthiness Review Certificate issued by the Danish Transport Authority was valid until 29.3.2014.

The aircraft was within the mass and balance limitations at the time of the serious incident.

Last inspection (200 hrs.) was performed at aircraft total time 5192:06 hrs.

Flight Manual

The P68 Observer Flight Manual (FM) NOR10.707-3 Revision 11 was approved by the Italian Civil Aviation Authority on 14.4.2010.

The FM Section 3 Emergency procedures contained among other information the following procedure:

*PROCEDURE FOR BEST PERFORMANCE AFTER ENGINE FAILURE DURING CRUISE FLIGHT.*

1) *Inoperative Engine – SECURE.*
   a) *Throttle – CLOSE*
   b) *Propeller – FEATHER*
   c) *Mixture – IDLE CUT-OFF*
2) *Operative Engine – ADJUST as required.*
3) *Trim Tabs – ADJUST.*
4) *Fuel Valves Position*
   a) *Inoperative Engine – ENG. SHUT-OFF*
   b) *Operative Engine – ON (also see Crossfeed Procedure)*
5) *Electrical Load – DECREASE to minimum required*
6) *As soon as practical – LAND.*

Engine information
The engines were manufactured in the United States of America by Avco Lycoming a division of Avco Corporation.

Engine # 1 information:

| | |
|---|---|
| Engine position: | # 1 (left wing) |
| Type: | IO-360-A1B6 |
| S/N: | L-20085-51A |
| Valve type: | Angle valve cylinders |
| Rated horsepower: | 200 HP |
| Rated speed: | 2700 RPM |
| Time since new: | 5162 hrs. |
| Time since overhaul: | 1593 hrs. |
| Date overhauled: | 27.2.2008 |
| Time since last inspection: | 50:09 hrs. |
| Type of last inspection: | 200 hrs. |

In connection with the last inspection (200 hrs.) it was revealed that cylinder # 3 (aft/right) compression (marked with yellow in the below table) was low (Engine hrs. 1543:24).

Cylinder compression test results:

| Cylinder no.: | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Psi: | 78 | 77 | 48 | 77 |

Cylinder # 3 was therefore removed from the engine and send to an authorized engine repair shop. The cylinder was reinstalled after repair (exhaust valve and piston rings replaced).

Engine # 2 information:

| | |
|---|---|
| Engine position: | # 2 (right wing) |
| Type: | IO-360-A1B6 |
| S/N: | RL-23176-51A |
| Valve type: | Angle valve cylinders |
| Rated horsepower: | 200 HP |
| Rated speed: | 2700 RPM |
| Time since new: | 3551 hrs. |
| Time since overhaul: | 1863 hrs. |
| Date overhauled: | 28.3.2006 |
| Time since last inspection: | 50:09 hrs. |
| Type of last inspection: | 200 hrs. |

Propeller information
The constant speed propellers were manufactured in the United States of America by Hartzell Propeller Inc.
The type of the two bladed propellers was defined as model HC-C2YK-2C.

**Meteorological information**
Actual weather for EKOD at the time of the serious incident:

| | |
|---|---|
| Visibility: | 10 km. |
| Clouds: | 1/8 22.000 ft. |
| Temperature - dewpoint: | 11°C - 6°C |
| Wind: | 230° 11 kt. |
| QNH: | 1021 hPa |

**Aerodrome information**
The pilot diverted to EKOD and communicated with AFIS on 119.525 MHz.
Landing was performed on the 2000 meter long and 40 meter wide runway 24.

**Engine examinations**
Engine # 1 examination
The engine was examined visually and it was revealed that the gasket between the intake port of the cylinder and the inlet manifold tube was missing.

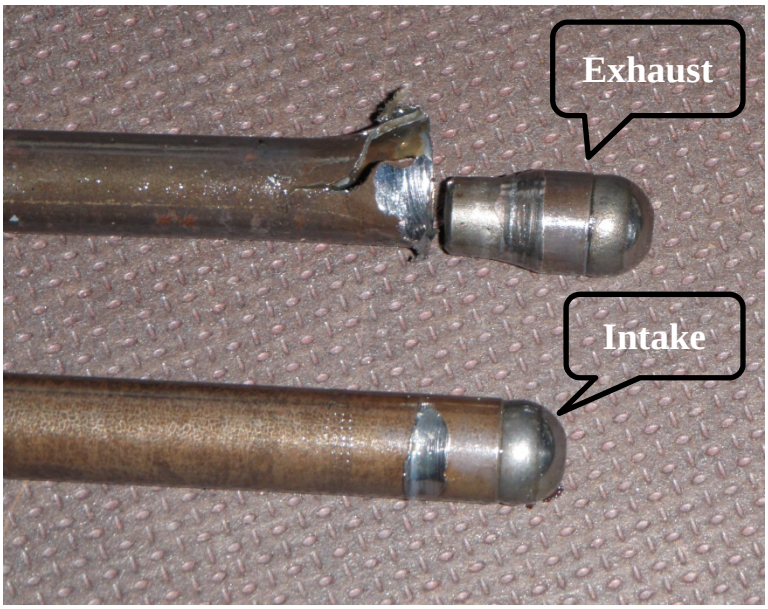
The engine was turned by hand without any findings or noise heard from inside the engine.

The valve covers were removed, the engine was turned by hand and it was revealed that cylinder # 3 (right/aft) exhaust valve did not open.

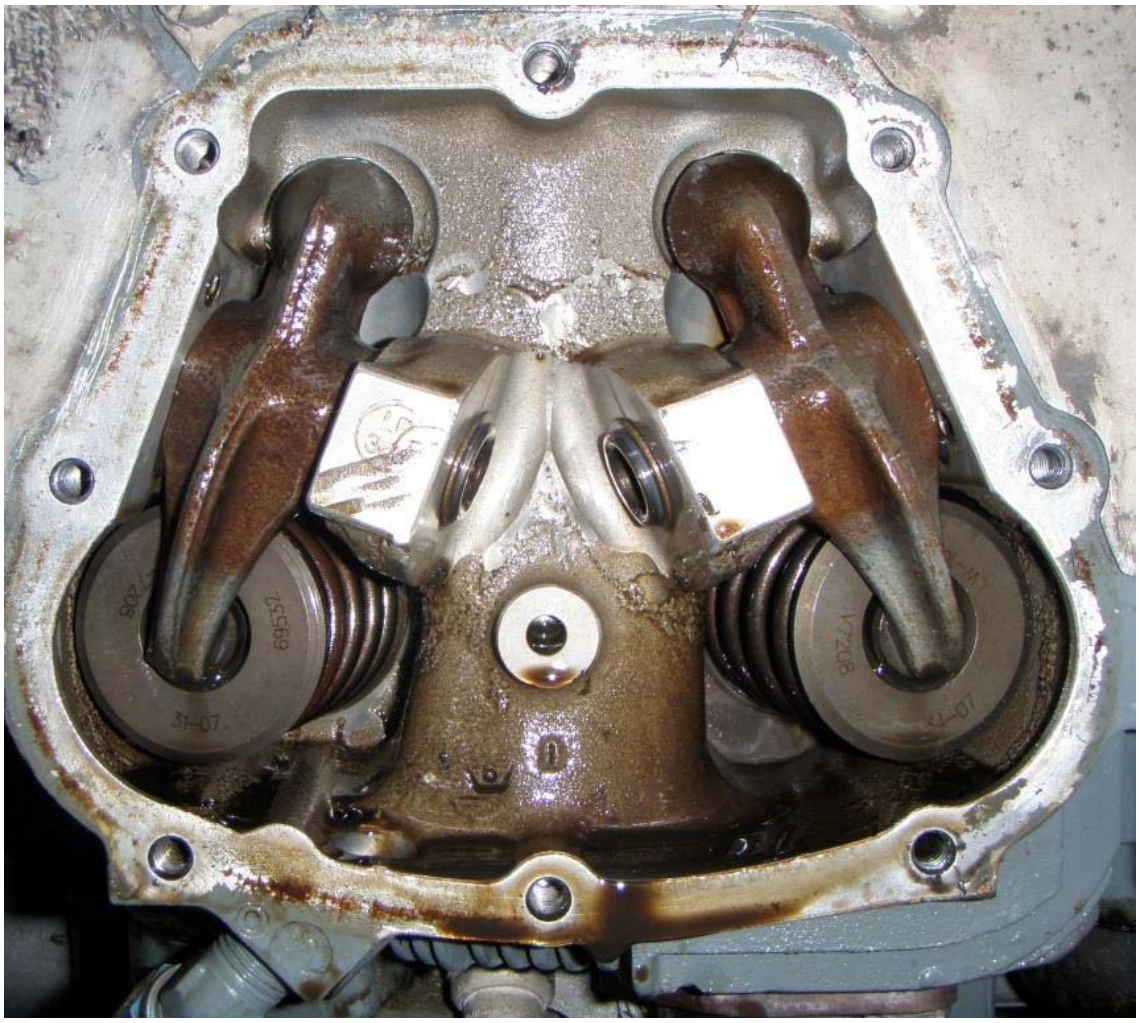
The examination also revealed that the exhaust and intake valve rocker arms were interchanged.

The picture next page shows the rocker arm installation of cylinder # 3.
It can be seen, that the rocker arms are displaced inwards and not aligned with the push tube bores in top of the cylinder.
The exhaust rocker arm was installed on the intake side and vice versa.
In addition it was revealed, that the push tubes were forced to operate in a displaced inward position.

As can be seen on the picture below, the exhaust valve push tube was damaged and broken up.
The intake valve push tube had impact wear marks on the top end of the tubing.
It was revealed that this damage was a result of contact with the top end of the push tubes in the push tube bores of the cylinder.



The picture below shows the rocker arms installation of another cylinder (Intake left and exhaust right). Note that the rocker arms are aligned with the push tube bores.



Rocker arm installation
As shown on the picture below, cylinder # 3 was partly hidden by the leading edge of the left wing.

According to the maintenance shop, the repaired cylinder was installed on the engine without the rocker arms attached to the cylinder due to lack of space on the aircraft.
The rocker arms were installed on the cylinder afterwards.

The maintenance shop mechanic that installed the rocker arms was of the opinion, that the rocker arms were interchangeable.
The mechanic explained that he had experience with the IO-360 parallel valve engines and that he was not aware of the different types of rocker arms on the different type of IO-360 engines (parallel or angle valve).

Furthermore, the rocker arms were normally installed on the cylinders by the engine shop.

A specific procedure about the different rocker arm assemblies and installations was not available to the mechanic at the time of the installation work.
The work was in general based on the skills of the mechanics.

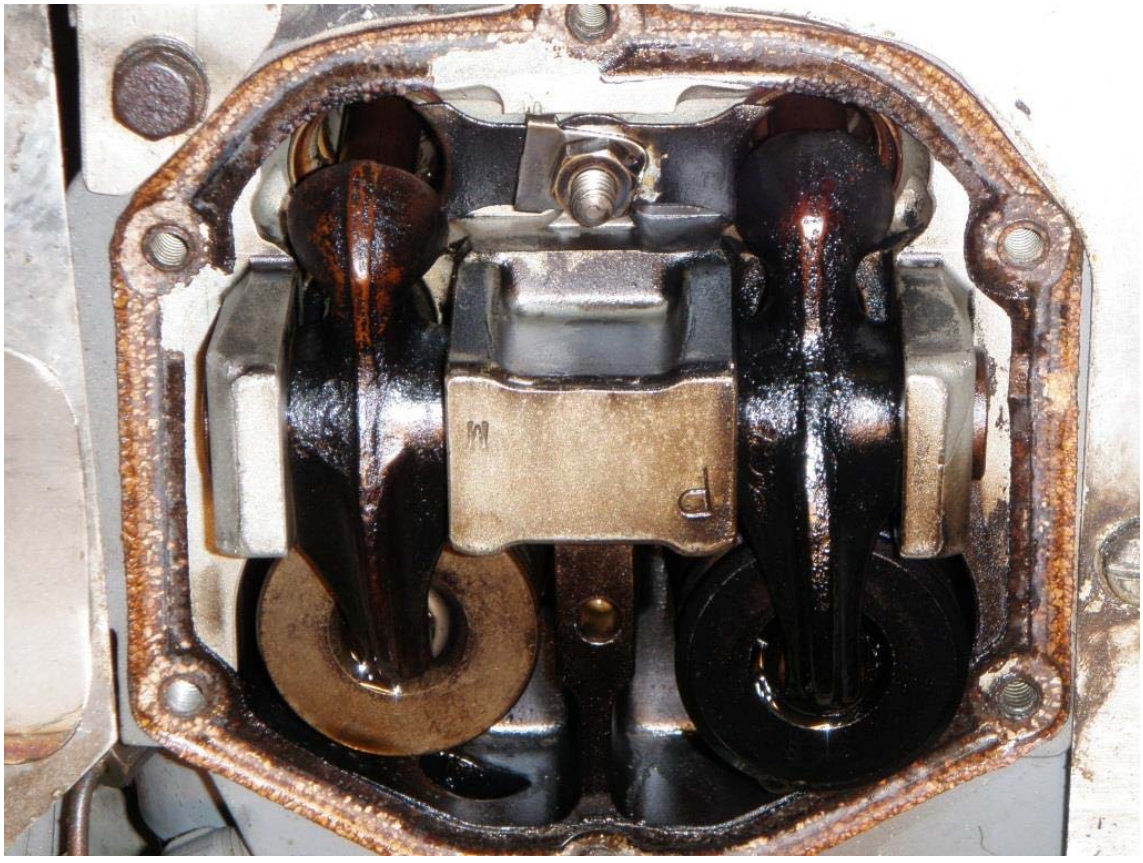
Information and cautions about rocker arm assemblies and installation guidance were available from the Lycoming Overhaul Manual, but not known to the mechanic that installed the rocker arms.

The rocker arms were installed in random order.
It was not noticed that the push tube end of the rocker arms did not align with the push tube bores.
The installation work was inspected by another mechanic without remarks.

IO-360 differences
The Lycoming IO-360 engine has either parallel valve cylinders or angle valve cylinders.
Unlike the rocker arms of the parallel valve cylinders where the intake and exhaust rocker arms are interchangeable, rocker arms are never interchangeable on the angle valve cylinders.
The IO-360 angle valve cylinders have hemispherical shaped combustion chambers. The IO-360 parallel valve cylinder has flat or traditional shaped combustion chambers.

According to the Overhaul Manual caution, exhaust and intake rocker assemblies are different due to the angle of the valves in the angle valve cylinder version.

A parallel valve cylinder from another engine is shown below for comparison to the angle valve cylinder.



Engine # 2 examination and test flight
The engine was examined visually without remarks.
Ground run was performed without remarks.

Test flight was performed circling around EKOD.
Normal take-off and level flight was performed. Both engines performed as normal without remarks.

The pilot demonstrated how the serious incident flight was performed.
From cruise power setting on both engines, the left engine (# 1) power lever was drawn back to idle and the right engine (# 2) power lever was selected full forward. The aircraft was trimmed to compensate for the power imbalance and the drag created by the non-feathered left propeller.

Engine # 2 cylinder and oil temperature increased.
After a few minutes of flight the cylinder temperature reached a temperature just below the “red” line. (According to the Flight Manual the cylinder temperature limit (red line) was 475° F (246° C).

To prevent engine damage and overstress (increased pressure in the cylinders) from operating the engine at high power / low RPM it was decided not to continue the test flight further under this condition.
The propeller lever was selected forward to increase engine RPM and as a result of this the cylinder temperature began to decrease.

Except for the high cylinder temperature the engine performed without remarks during the test flight.

Since the serious incident occurred and at that time with approx. 5241 total flight hours on the aircraft, it accumulated 143 flight hours until the next 200 hours inspection on 21.8.2013 without remarks on engine # 2.

## ANALYSIS

### General

The pilot was properly licensed.

The aircraft had a valid Airworthiness Review Certificate.

The aircraft was within the mass and balance limitations at the time of the serious incident.

### Engine # 1 failure and the single engine operation

In cruise flight the pilot observed abnormal mechanical noise from the left engine and he decided to reduce the left engine power to run at idle and divert the flight to EKOD.

If it is possible to hear abnormal mechanical noise from an engine, it normally means that something inside the engine is broken, heavily damaged or on its way to be.

The AIB DK is of the opinion that in case of a mechanical failure on a twin engine aircraft the damaged engine should be shut down and the propeller feathered to prevent further damage.
The reason for this is that it is unknown how a damaged engine will behave.
The engine could disintegrate and cause heavy damage or fire on the aircraft.

Another viewpoint is that a non-feathered propeller creates a lot of drag and therefore, hard and unnecessary work is required of the other engine.

However, in this case it could be argued that it was a good idea to have the damaged engine running in spare (three cylinders were still working). At least as long as the flight was over the water.

### Engine # 1 mechanical failure

Maintenance work almost 50 flight hours before the engine failure sowed the seeds of the failure of cylinder # 3.

The engine examination revealed that because the exhaust and the intake rocker arms were interchanged, the push tubes were forced to be misaligned in the push tube bores.
Every time the valves were opened by the push tubes, the tubes came in contact with the push tubes in top of the push tube bores of the cylinder.

Over time (almost 50 hrs.) this caused damaged to the push tubes and finally caused the exhaust push tube to break up.
As a result hereof the exhaust valve could no longer be opened.

It is the opinion of the AIB DK that because of the closed exhaust valve most of the noise heard by the pilot came from the trapped combustion and high cylinder pressure of cylinder # 3.

This probably also caused the intake gasket between the intake port of the cylinder and the intake manifold tube to blow out.

**Human factors and procedures**

The rocker arm installation work on cylinder # 3 on the aircraft was based on the skills of the mechanics.
The AIB DK finds that procedures concerning information about the different rocker arm assemblies and specific installation instructions could have prevented the rocker arms to be interchanged.
The rocker arms of the angle valve cylinders are not identical to each other.

The mechanic was experienced with the parallel valve version of the IO-360 engine and the interchangeable rocker arms fitted to the cylinders of this type of engine.
Therefore, he was unaware of the fact that the rocker arms were not interchangeable on the angle valve version of the IO-360 engine.

The AIB DK relates the inspection of the work performed by another mechanic to human factors explained as “trust” among colleges and the lack of space on the aircraft.
However, specific installation instructions and cautions could have helped the other mechanic to be focused on what to look for.

**Engine # 2 intermittent loss of power**

Engine ground run and test flight was performed without remarks except for high cylinder temperature.
The engine showed no signs of loss of power. However, the AIB DK cannot exclude that engine # 2 intermittent loss of power would have occurred if the test flight was continued for a longer period of time.

But, to prevent engine damage and overstress (increased pressure in the cylinders) from operating the engine at high power / low RPM it was decided not to continue the test flight further under this condition.

It is the opinion of the AIB DK that the intermittent loss of power probably was caused by engine overstress due to high power / low RPM.
High power / low RPM operation will increase the pressure in the cylinders.
Basically, the lower RPM means that the valves will be open for a longer period of time and more air will enter the cylinders on the intake stroke.
Detonation instead of normal combustion is likely to occur. Loss of power and risk of engine damage is present.

The scenario can be compared to drive a car up a very steep hill in $5^{th}$ gear with full throttle.
The car engine will lose its breath and you must gear down to get the engine working properly again.

This scenario is exactly the same in an aircraft. The gear is the propeller lever.
An aircraft engine will also lose its breath if it is heavy loaded over time at low RPM and you will need to “gear down” with the propeller lever.

It is the opinion of the AIB DK that engine # 2 was excessive loaded and probably lost its breath and power intermittent in the situation where it worked to keep the aircraft flying single engine with the other engine and propeller producing a lot of drag.

In the light of the fact that the engine has performed normally in the period after the serious incident the AIB DK is of the opinion that the intermittent engine power loss was caused by excessive load and could have been prevented by increased propeller RPM.

**CONCLUSIONS**

As a consequence of a mechanical failure of engine # 1 caused by a broken exhaust valve push tube, the flight was diverted to Odense Airport powered by engine # 2 only.
The most probable cause of the intermittent power loss of engine # 2 reported by the pilot, was excessive load due to high power / low RPM operation of the engine.

Contributing factors to the serious incident was:

- Engine # 1, cylinder # 3 valve rocker arms were interchanged during maintenance work.
- Procedures concerning information about the different rocker arm assemblies and a specific installation instruction were not available to the mechanics.
- The engines were not operated according to the Flight Manual.
- The non-feathered engine # 1 propeller created excessive drag.

**SAFETY RECOMMENDATION**

The AIB DK issued no recommendations based on this investigation.

The AIB DK will use this opportunity to remind pilots about the following:

In case of a mechanical failure on a twin engine aircraft the damaged engine should be shut down and the propeller feathered to prevent further damage.
The reason for this is that it is unknown how a damaged engine will behave.
The engine could disintegrate and cause heavy damage or fire on the aircraft.

Another important viewpoint is that a non-feathered propeller creates a lot of drag and therefore, hard and unnecessary work is required of the other engine.