



Dry Vacuum Pumps

AWB 37-003 Issue : 1
Date : 9 April 2015

1. Effectivity

All aircraft equipped with dry vacuum/pressure pumps used to power air-driven gyroscopic instruments such as the artificial horizon, turn and bank and directional gyros.

2. Purpose

To provide general servicing and troubleshooting information on dry vacuum pumps and to complement pump and aircraft manufacturers' information in order to better ensure vacuum system reliability.

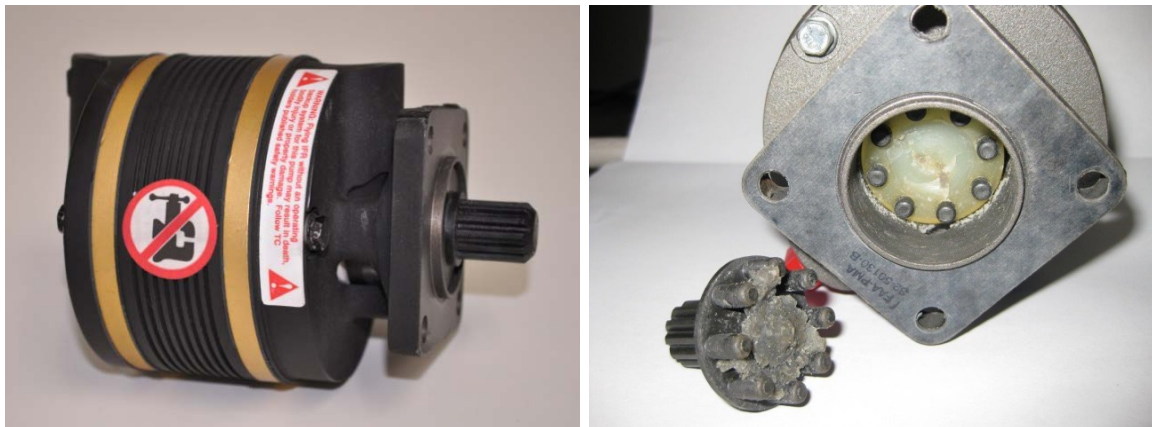


Figure 1 Typical dry vacuum pump (left), sheared vacuum pump coupling (right)

3. Background

Dry vacuum pumps can fail catastrophically and may also provide little or no indication to warn the pilot of imminent failure. Loss of vacuum will result in a gradual run down of the air driven gyros and the loss of attitude and navigation instruments such as the artificial horizon, turn and bank and directional gyros. This may lead to loss of control during instrument flight.

An [AOPA \(USA\) Air Safety Foundation report](#), published in 1999, based on National Transport Safety Bureau (NTSB) accident data found that from 1983 to 1997, 80% of all accidents attributed to vacuum pump failures were fatal. Australia has also suffered a number of fatal accidents directly attributable to the loss of vacuum to the air-driven gyroscopic flight instruments ([ATSB Report](#)).



Dry Vacuum Pumps

AWB 37-003 **Issue :** 1
Date : 9 April 2015

The most common mode of failure in vacuum pumps is fragmentation and seizure of the pump rotor and vanes resulting in the frangible coupling between the engine and the pump shearing. Pumps are subject to this failure for a number of reasons:

- Oil and solvent contamination
- Foreign objects and particles
- Overheating
- Incorrect rotation direction
- Propeller strike damage
- Dropped or damaged before installation
- Incorrect installation
- Time expired or worn pumps

4. Vacuum Pump design

A short introduction to the design and construction of the typical dry vacuum pump (or air pump) may assist in understanding why pumps fail. Dry vacuum pumps are simple positive displacement pumps. Carbon-graphite vanes sit loosely inside a central carbon-graphite rotor which is located inside a round steel housing with an oval cavity, in which sit the rotor and vanes (see Figure 2).



Figure 2 - Internal view of a serviceable dry vacuum pump (left) and a failed pump (right)

This rotor is typically driven by the aircraft's engine. As the engine runs, the rotor turns, causing the vanes to be flung outwards, and the edges of the vanes seal against the housing via centrifugal force. As the vanes rotate (in the above picture, the pump would rotate clockwise), air from the gyro instruments is drawn into the pump by the increasing volume created by the vane as it moves out of its slot and follows the oval shape of the housing. At the point where the air would start to be compressed, the preceding vane uncovers the exhaust port and the air is forced through the outlet as the volume decreases. The carbon-graphite vanes are lubricated only by a fine



graphite powder, created by the vanes themselves as they wear down, hence the term “dry” vacuum pump. These pumps can be used to provide either positive pressure or suction, depending on the way the pump is connected to the aircraft.

5. Typical causes of failure

The following identifies common causes of vacuum pump failure and may help during investigation into identifying the mechanism(s) of the last pump failure. Simply replacing a failed vacuum pump with a new one without considering, investigating or understanding why the pump failed in the first place may lead to the new pump failing very shortly after installation.

Oil and solvent contamination

When any contaminant, such as engine oil, mixes with the dry carbon-graphite powder that lubricates the pump, it forms a thick sludge that will quickly cause the pump to seize. One main source of engine oil is a leaky drive pad seal or gasket that can quickly allow oil to enter the pump housing and damage the pump.

In a similar manner to oil, solvents, such as those used to wash the engine can also contaminate and ruin the pump. This commonly occurs when washing the engine during maintenance, where the solvent can enter through the drive coupling or discharge port.

Foreign objects and particles

Carbon-graphite is brittle and susceptible to failure when solid contaminants enter the pump housing. Fragments of the interior of old rubber hoses can break off in operation and jam the pump. Even once a new pump is installed there is a good chance that carbon or other contaminants such as fragments from the old pump or from failed vacuum hoses can remain in new the hoses connecting the pump to the rest of the vacuum system. This can be enough to cause the new pump to fail soon after installation.

Pump manufacturers are particular to advise that Teflon tape on any threaded fittings is not to be used, as they are prone to being ingested by the pump and causing premature failure. It is always worthwhile to clean the inside of the hoses in the vacuum system after a pump failure.



Overheating

It is easy to forget that the vacuum pump is only one part of the vacuum system. If there is an overall deterioration of the vacuum pump system, such as dirty filters, kinked or obstructed hoses, these problems can constrict the airflow through the system, resulting in a low reading on the vacuum gauge, particularly at altitude. One attractively simple (and commonly done) “fix” is to adjust the vacuum regulator, which will increase the reading of the vacuum gauge, seemingly solving the issue. This forces the pump to work even harder to overcome the constricted system and to provide the required airflow for the instruments. As with any system forced to work harder than designed, the pump will begin to overheat and most likely fail prematurely.

Aircraft with booted deice systems place a heavy burden on vacuum pumps. During normal operation, pneumatic deice boots cycle on and off alternately inflating and deflating. The FAA has received a number of Service Difficulty Reports of sticking deice boot valves in some aircraft, with the valve hanging partially in the inflate position. When this occurs the vacuum pump is put under stress, raising the temperature and potentially causing permanent damage.

Shrivelled or melted stickers (such as the “DO NOT VICE” sticker) on the pump are a good indication that the pump has been **overheating**.

Incorrect rotation direction

Most vacuum pumps are designed to run in one direction only; clockwise (CW) or counter clockwise (CCW). Simply pulling the propeller backwards to “test” cylinder compressions may fail the pump by forcing the vanes to rotate in a direction opposite to their intended design. In order to prevent the vacuum pumps from being operated in reverse, never turn the propeller backwards. Installation of the incorrect orientation pump can also cause premature failure in a similar manner.

Propeller strike damage

Any time there is a propeller strike, the inertial and impact forces put severe stress on the engine as well as any accessories connected to it. This includes the vacuum pump. Most manufacturers mandate that after a sudden engine stoppage, the vacuum pump should be replaced.



Dropped or damaged before installation

The carbon vanes and rotor inside the pump housing are particularly vulnerable to shock damage. If the housing is subject to impact damage, such as being dropped, the vanes or rotor may suffer minute cracking. This will lead to the pump not functioning as reliably as intended. Pump manufacturers usually require replacement of the vacuum pump if it is dropped. Another common way vacuum pumps get damaged is when they are incorrectly clamped in a vice. Vacuum pumps should **never be clamped by the housing**; they should only be carefully clamped by the mounting plate. New pumps should have a “do not vice” warning attached to the pump housing.

Incorrect installation

Some pumps have failed prematurely because the pump was not properly seated on the drive pad. The gasket is an important part of the installation, in many cases blocking off the oil port that was used for older, wet vacuum pumps. Incorrect pump installations can cause engine failure. A report of an aircraft losing seven U.S. quarts (≈ 6.58 litres) of oil during flight was traced to loose vacuum pump mounting nuts which had allowed the pump and gasket to separate slightly from the drive pad, uncovering the oil pressure port, resulting in the loss of engine oil overboard. In another case, complete loss of engine oil pressure while in flight resulted in a forced landing. A trail of oil was found on the taxiway and led to a pool of engine oil where the engine was first started after the new pump had been installed incorrectly to the engine.

Time expired or worn pumps

The carbon graphite vanes in the vacuum pump will eventually wear down to the point where the pump suffers loss of performance and requires replacement. Sometimes the vanes will wear down to the extent that they come out of the slot in the rotor and jam and fracture the hub or rotor.

Vacuum pumps of more recent design now have vane wear indicator ports or other ways of assessing serviceability that allow the wear of the vanes to be determined and permit pump replacement before an in-flight failure occurs.



6. Recommendations

In order to ensure vacuum pump reliability, CASA recommends the following:

a. Adhere to manufacturer's instructions

Always follow the aircraft and component manufacturers approved maintenance data to ensure the continuing airworthiness of vacuum pump and vacuum system components. This includes inspecting and retiring the pump at the required intervals.

b. Replace system filters

When installing a new pump, vacuum system filters should also be replaced. Clogged filters can reduce vacuum system efficiency and overstress the pump which may result in premature failure.

c. Discard stripped or damaged fittings

Make sure to discard any unserviceable fittings which have damaged threads, rounded corners or kinked tubes. When installing fittings, do not use Teflon® tape, 'pipe dope' or any other unapproved thread lubricants.

d. Check the pump pad for oil leaks

Oil found on the drive pad generally indicates that the drive seal has failed. Replace the seal and clean up any oil that could contaminate the vacuum system.

e. Always install the pump with a new gasket

Manufacturers are quick to point out that a lot of premature failures occur when the mating gasket is reused. Manufacturers recommend to always replace the gasket when replacing the vacuum pump to remove all remnants of the old gasket, and to take care during installation to ensure the pump sits squarely on the pad and all nuts are torqued correctly.



f. Check the hoses.

If the previous pump has failed, thoroughly clean the entire vacuum system and inspect the vacuum system hoses internally and externally for contamination and condition, as residue can clog and destroy a new pump prematurely. Be suspicious of hoses which may look acceptable externally, but feel hard or brittle when flexed - even if the aircraft records indicate the hose is not due for the 10 year replacement required by some aircraft manufacturers. Replace the hoses as necessary before further flight.

g. Conduct an engine run

After installing a new vacuum pump, conduct an engine run to test the correct functioning of the aircraft's systems and to check for engine oil leaks. For twin-engine aircraft and single engine aircraft with a standby, electrically operated vacuum pump, see CASA AWB 37-002, which describes functional vacuum system testing for dual pump systems.

7. Useful links

The following websites have useful information and were correct at the time of publication (hold ctrl and then left-click the link to access the webpage):

[Why Vacuum Pumps Fail](#)

AOPA (USA) report - [In-emergencies: Vacuum Pump Failure](#)

Office of Aerospace Medicine Report - [DOT/FAA/AM-02-19](#)

[ATSB Report: 199502371](#)

8. Related CASA AWBs

[AWB 37-002](#) – Aircraft Gyro Instrument Vacuum / Pressure Systems – Functional Testing

[AWB 31-008](#) – Gyroscopic Instrument Reliability

9. Reporting

All reports of vacuum pump failures should be reported to CASA via the SDR system, or sent via email to SDR@casa.gov.au.



AIRWORTHINESS BULLETIN

Dry Vacuum Pumps

AWB 37-003 **Issue :** 1
Date : 9 April 2015

10. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link e-mail address:

AirworthinessBulletin@casa.gov.au

or in writing, to:

Airworthiness and Engineering Standards Branch
Standards Division
Civil Aviation Safety Authority
GPO Box 2005, Canberra, ACT, 2601