Approaching Zero Failure

Gyro Instrument Pneumatic Systems

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The aircraft pneumatic gyro instrument system is a very simple system. In fact, the system is so simple we tend to ignore some simple facts about its operation. There are two basic systems—one operates on vacuum pressure (pressure less than atmospheric pressure), and one operates on pressure above the atmospheric pressure. They are most often referred to as vacuum or pressure systems. Like simple circuits in an electrical or electronic circuit, if you inner connect enough of these simple pneumatic systems, it does complicate them to some degree.

A statement often used in reference to aircraft maintenance is, "Good judgment comes from experience and a lot of the experience comes from poor judgment." When it comes to the pneumatic gyro systems in our aircraft, I think it is safe to say we have had enough experience (good and bad), that we should be approaching zero failure in these systems.

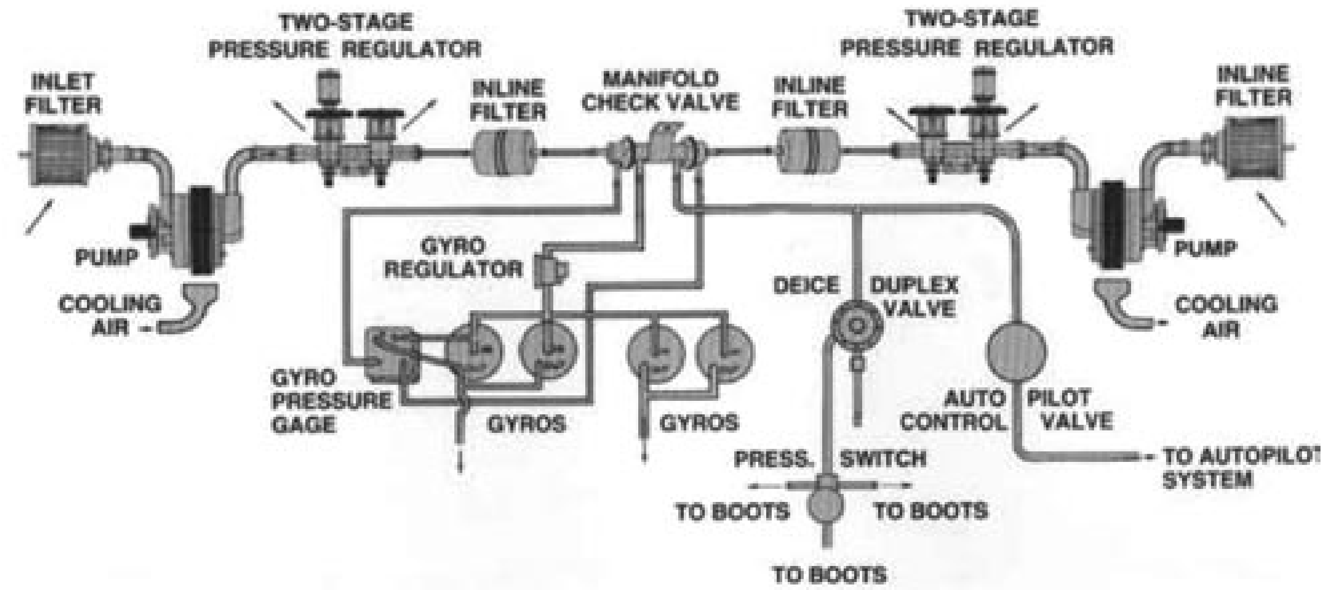
CV1J4 "Clear View" Inline Air Filter

Our experience should be telling us, "Of all the components in these pneumatic systems the gyro instruments and the pumps have the honor of having the highest failure rate. Seldom do any of these items fail without giving some prior indication."

"Why Air?"

To understand why we have air driven gyro instruments in many of today's general aviation aircraft one must look at the evolution of gyro instrumentation in aircraft. The gyro was here long before the airplane and man understood the principles of its operation. Early aviators realized the gyro could give them a reference in space almost independent of the earth. With this stable reference they could determine the attitude and movement of the aircraft in space in reference to the earth.

One description of a gyro is a spinning mass rotating on an axis, much like our earth. In the aircraft gyro instrument system, the energy to spin the rotor (the spinning mass) is primarily derived from one of two methods: either airflow over the outer surface of the rotor in the direction of rotation, or a rotating electromagnetic field around the rotor.



Twin Engine. Dual Pressure Pumps—Pneumatic Gyro Instrument System

At the time they were developing gyro instruments our aircraft had very little, if any, electrical systems. Weight was a big factor. A Ventura tube that could develop the high volume, low-negative air pressure (vacuum) required to spin the rotor was more economical, and much lighter than an electrical system that could develop the required rotating magnetic field. With the technology available at that time, the benefits and costs of the air driven rotor simply outweighed the electric. The flow of the exhausting air from the rotor housing also was beneficial by providing a compensating method for rotor drift and maintaining the desired position of rotor axis. Since the first aircraft gyro instruments were built, we have came a long way in the development of electrical energy. I am reasonably sure if we were to start from scratch to build a gyro instrument with today's technology, we would surely be using some type of rotating magnetic field to spin the rotor.

As the industry advanced into larger aircraft with more efficient engines, along came the never-ending desire to fly faster. The Ventura tube on the exterior of the airframe created an undesirable drag. The advantages, primarily the cost of an air-driven gyro, still outweighed the electrical-driven, so an alternative method was introduced—the engine-driven vacuum pump.

The engine-driven "wet vacuum pump" as it was known, was the answer to the elimination of the unwanted Ventura tube. It worked well, and we still have aircraft in service today that use this system to operate their pneumatic gyro instruments. The system did have its undesirable conditions, though. To lubricate and seal the pneumatic pumping gears of the pump, oil from the engine was bled into them. An oil separator was installed to remove the oil from the exhausting air. The separator system was not perfect; it did not remove all the oil from the air prior to discharging it to the exterior of the aircraft. This would leave an oil film on the exterior of the aircraft—not a desired situation on a clean aircraft. Over a period of time, this oil film would also work it's way into the gyro instrument causing them to function improperly. As aircraft engines developed into cleaner operating units, this exhausting oil film became

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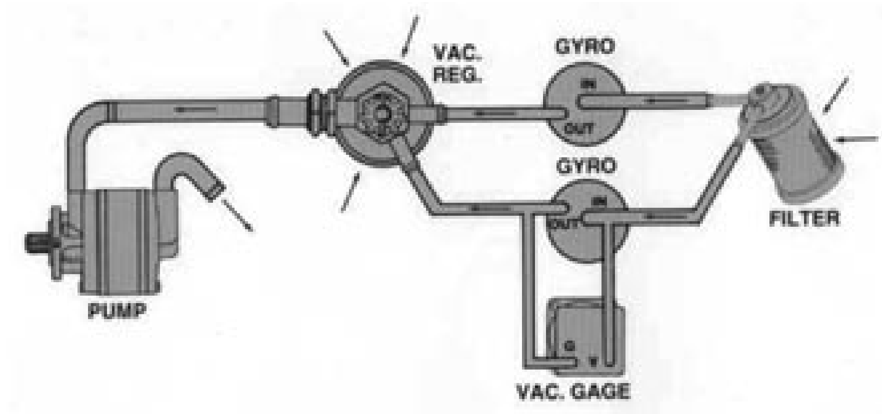
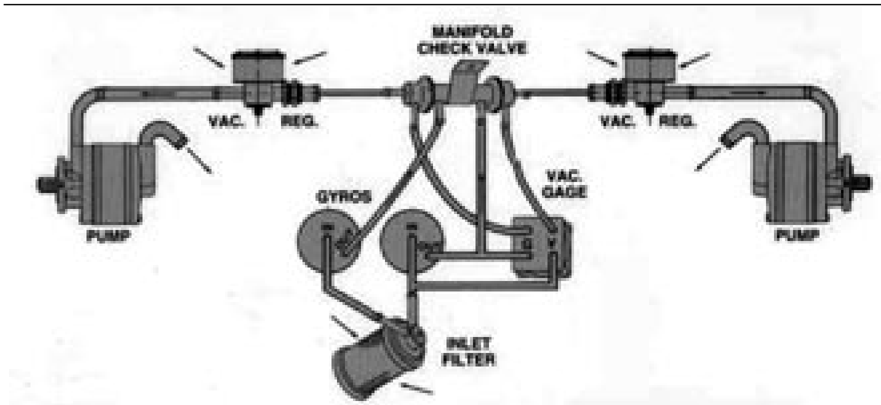
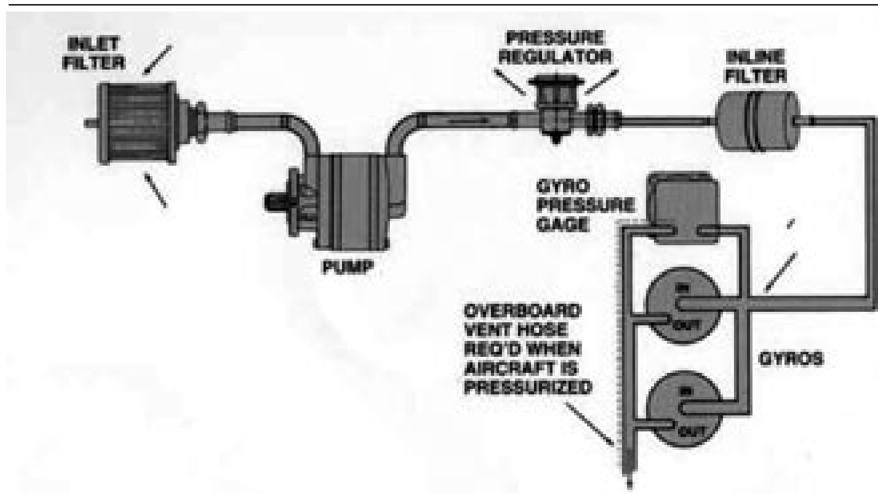


Single Engine, Single Vacuum Pump—Pneumatic Gyro Instrument System



Twin Engine, Dual Vacuum Pumps—Pneumatic Gyro Instrument System



Single Engine, Single Pressure Pump—Pneumatic Gyro Instrument System

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a very undesirable condition, and the search was on for a more desirable system to operate the pneumatic gyro instruments. The engine-driven dry air pump was then introduced to the aviation industry.

Gyro Instrument Dry Pneumatic Pumps

One advantage the dry air pump had over the Ventura and the wet pump was it could be used in either a vacuum or pressure pump—the inlet port of the pump providing vacuum or the outlet port providing pressure. In some cases both ports are used—the inlet port providing for vacuum gyro instruments and the outlet port providing pressure for de-ice boots.

Why can we operate a dry pneumatic (vacuum or pressure) pump in a shop environment for thousands of hours with a very low failure rate? Why, when the same type pump is operating in the aircraft environment we get fewer operating hours and a much higher failure rate? For many years I have looked for an answer to these questions. Was the aircraft-type pump an inferior product? The cost of these pumps surely would not suggest this. After much thought, I have concluded there are no simple answers. Perhaps the closest answer would be those individuals who install, maintain, and operate these aircraft pneumatic systems lack the knowledge of the perimeters these pumps should be maintained and operated within.

Most dry pneumatic pump failures are caused from either contamination entering the pump, excessive wearing of the carbon parts in the pump, or operation of the system outside the designed perimeters. The pump was designed to operate with clean, dry air. Influx of almost anything will cause pump failure. The very small clearance between the rotor and the walls of the rotor cavity leaves very little room for anything other than air to pass. Almost any type of contamination will cause the rotor to bind in the rotor cavity, resulting in pump failure.

For many years Teflon tape was the No. 1 contaminating material causing pneumatic pump failure. Using Teflon tape in a gyro instrument pneumatic system is much like using acid core solder in an electrical circuit. Failure is going to occur, it is only a matter of time. While pneumatic pump manufacturers have done much to educate those maintaining these systems about the consequences of using Teflon tape, it is still used by some. The inlet and outlet on all the components in these pneumatic systems are either slip-on hose fittings or female tapered pipe thread. Neither of these type connections requires any type sealant to make an airtight seal. The only advantage to using any type of lubricant on tapered pipe threads is to prevent seizure of the male and female threads. The best procedure would be to use the manufacturer's recommendations for anti-seizure.

A second contaminate causing pneumatic pump failure, is moisture and other liquids. These liquids, when mixed with the carbon dust, do not pass through the pump without causing some pump damage. If this does not cause physical damage to the pump, at the very least it will cause sticky vanes, causing loss of compression. In a vacuum system these liquids can enter the system at any point, and will be drawn to the pump. In a pressure system the liquids will enter the pump through the pump's inlet port or the pump's drive shaft seal. This seal is primarily a dust seal; liquids can penetrate it, and gain entry to the rotor cavity.

The third type of contaminate causing pump failure is particles of rubber, carbon, and other materials. This type of contamination often depends on the technicians performing system maintenance. Their knowledge of the systems and their work habits will determine the amount of contamination. When the maintenance technicians have little knowledge of the systems and poor work habits, this contamination can be the cause of multiple and repeated pump failures. The pump in a vacuum system is the most susceptible to this type of contaminate, because like a vacuum cleaner, it will be draw-

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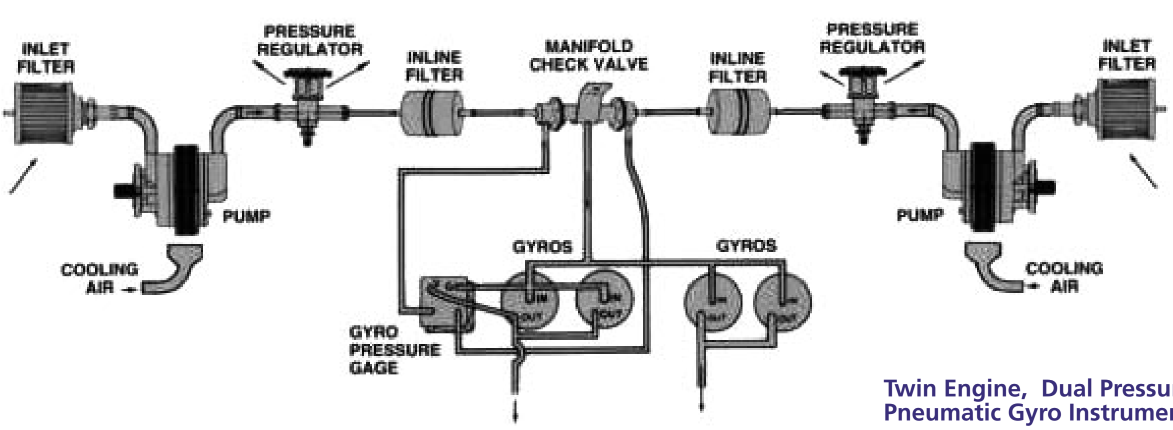

Twin Engine, Dual Pressure Pumps— Pneumatic Gyro Instrument System

PNEUMATIC GYROS

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ing clean or contaminated air from all parts of the system to the pump. This type of contamination is often the result of poor maintenance practices such as reusing old fittings without properly cleaning them when replacing the gyro instruments, pneumatic pump, or other components in the system.

The engine nacelle is designed to baffle the ram air around the engine cylinders to cool them. In this process there is a positive pressure built up in the engine nacelle. This pressure can sometimes be as much as 2 to 4 inches H2O above atmospheric pressure at the inlet filter for the gyro instruments. When a pump fails, often the carbon rotor and vanes break into many fine pieces. The positive pressure in the nacelle will cause air to flow through the system to the gyro instruments carrying the contaminating carbon bits with it. Failure to properly clean the system prior to installing a serviceable pump will more often than not result in a repeated pneumatic pump failure.

This is especially true with a vacuum system. Many manufacturers of the pneumatic gyro instruments left the outlet port (vacuum port) of their instruments with no filter, allowing an unrestricted flow of this contaminated air from the damaged pump to the interior of the gyro instrument. If this contamination of the gyro bearings does not cause immediate failure, it will surely shorten the life expectancy of the instrument. An inline filter would all but eliminate this contamination flowing through the system to the instruments.

A vent tube from the outlet of the vacuum pump to the exterior of the engine nacelle will eliminate the positive pressure in the engine nacelle from the outlet port of the pump. With this addition the pressure at the outlet port of the pump and the interior of the aircraft will be, approximately, the same and there would be no reverse airflow in the case of pump failure.

In many ways the dry-pump pneumatic systems can be compared to an electrical circuit. To visualize this, let us consider a simple electrical circuit containing an electrical generator and an electrical motor. If we increase the load on the motor the generator will have to produce more power to maintain the same motor speed. Any type of resistance in the circuit will create a voltage drop, and again the generator will have to produce more power to maintain the same motor speed. If there is power leakage through poor insulation, the generator will again have to produce more power to maintain the same speed. In a dry-pump pneumatic system, many facts parallel those of the electrical circuit. If we restrict the flow of the pump, we must increase pressure to overcome the resistance, to maintain the required airflow. If the interior of the lines or the line fittings are too small, have sharp turns or 90 degree line fittings, long connecting lines, or any other type of resistance to the flow, it will require the pump to increase pressure. Loose hose fittings, a leaky regulator, or anything in the system that is creating leaks, will require the pump to increase pressure. Like a generator in an electrical circuit, the operating temperature of the pump in a pneumatic system will increase as its power requirements increase.

While Advisory Circular 43.13.2A, Chapter 11, “ADDING OR RELOCATING INSTRUMENTS” is somewhat outdated with the pneumatic systems we have today, it makes some interesting comparison of air flow, resistance and pressure—such as Ohm’s Law (E = I x R) in an electrical system. Pressure = Air Flow x Resistance in pneumatic systems.

Reading this A.C. (43.13.2A, Chapter 11) will justify the use of the high flow fittings throughout these pneumatic systems. The traditional AN fittings are no match for the larger ID and the smooth turning surface of these high flow fittings that will greatly reduce resistance to air flow.

We most often think about pneumatic systems as having a low flow and high pressure. This type of air pressure system is common in most maintenance shops. While these systems have a very high pressure, few would have sufficient airflow to properly operate a pair of standard air-driven gyro instruments. The aircraft’s pitot-static system is another one of those systems where there is very little airflow. In these systems with a very low airflow, resistance to the airflow has very little effect on the pressure in the system. Compare the pneumatic gyro system to an electrical system. The electrical starter system on some of the large turbine engines would make a good comparison. Resistance that would be negligible in most electrical circuits has a very negative effect in those starter systems where the current flow is in the neighborhood of 1,000 amps. In this type of circuit a small resistance creates a large voltage drop in the circuit. In a high flow pneumatic system such as the aircraft pneumatic gyro instrument system there is a large loss of pressure across a small resistance in the system. Remember Ohms Law (E = I x R). Likewise, restrictions that would be negligible in most high-pressure low-flow pneumatic systems (like the maintenance shop high pressure air system or pitot-static system) will have a very negative effect in a high-flow low-pressure system such as the gyro instrument pneumatic system.

These pneumatic pumps are designed to operate within a particular temperature range. Life expectancy is based on these perimeters. To receive the maximum life from the pump, one should operate the pump within these limits wherever and whenever possible. Temperature and wear are proportional to one another—when the temperature goes up, so does the wear. The temperature and differential pressure of a pump are also proportional to one another—when the pressure goes up so does the temperature. The regulator in the system was designed to maintain a designed differential pressure across the inlet and outlet ports of the gyro instrument. Any loss of this differential pressure in the system between the pump and the gyro instrument will cause an increase in the differential pressure at the pump. Leaks and flow restrictions will cause this pressure loss.

Instruments with a higher than normal airflow will also cause a drop in the differential pressure across the instrument ports. Previously we mentioned the positive pressure built up in this engine nacelle. This pressure sometimes as much as 2 to 4 inches H2O positive pressure above the pressure in the cockpit and inlet ports of the gyro instruments. This requires the vacuum pump to have a differential vacuum as much as 2 to 4 inches H2O higher to compensate for this positive pressure. This increase of differential pressure in the pump will cause the temperature of the pump to rise, causing increased wear. The addition of a vent tube from the intake of the vacuum pump to the exterior of the engine nacelle will shield this positive engine nacelle pressure from the pump's inlet port.

The Pneumatic Gyro Instruments

Within the case of the gyro instrument the air flows through the air seals of the gimbals' bearings and across the rotor, spinning the rotor on its axes. The exhausting airflow from the rotor housing applies precession forces to maintain a reference to earth in the attitude gyro and the attitude of the aircraft in the directional gyro. The mechanics of the gyro instrument remain the same, whether it is driven by the airflow in a pressure or vacuum system. The airflow through the instrument is a result of the differential pressure between the instrument's air inlet and the air outlet ports. In a vacuum system the pressure at the air outlet port is lowered below atmospheric pressure. The differential pressure between the atmosphere and the pump now forces air to flow through the instrument. In a pressure system the pressure at the air inlet port is raised above atmospheric pressure and the airflow is in the same direction.

The weight of the rotor, and the stabilizing forces created when it is spinning, is no match for the small friction-free bearings required in the supporting gimbals for proper operation. The small friction-free ball bearings of these gyro instruments are lubricated with light oil. With the exception of exceeding the instrument's operating limits, this oil cushion makes the instrument bearings less susceptible to mechanical damage when operating in the aircraft. Most often the mechanical damage to these bearings is inflected sometime after it leaves the hands of the manufacturing or overhauling technician and prior to the first run in the aircraft. Once the instrument is operating in the aircraft we are faced with another declining factor, "bearing contamination."

These very small friction-free bearings are now operating in an environment created by the gyro instrument pneumatic system. Contamination in this air will cause friction in these bearings, and improper and unreliable operation will follow.

In a vacuum system, there is a filter connected to the air inlet port of the instruments, filtering the air entering the instrument. This filter will remove most contaminates from the air, but moisture is not one of them. Periodic replacement of this filter will ensure clean airflow through the instruments. The vacuum system has an unrestricted airline connecting the inlet port of the vacuum pump to the outlet port of the instruments. Over a period of time the carbon dust from the wearing carbon vanes in the pump will work its way upstream of the airflow, causing contamination in the instrument bearings. This contamination will greatly shorten the life expectancy of the gyro instruments. This problem can be very easily corrected by installing an inline filter in this line, preferably close to the pump's inlet port. This will restrict the flow of carbon dust and other contaminates to the instrument. A clear, see-through filter is best for this installation, because it can be monitored for contamination. Carbon dust is the No. 1 contaminating source causing instrument failure in a vacuum system.

In a pressure system there is an inline filter in the line between the outlet port of the pump and the inlet port of the gyro instrument. This restricts, but does not completely stop, the flow of all contaminates to the instrument. Some carbon dust and moisture will leak through the filter; this leakage can be greatly reduced by keeping a fresh, clean filter installed. Unfortunately when air is compressed, moisture is created. Although the pressure is extremely low (approximately 2.5 to 4.5 PSI), this system is no exception. Moisture is the No. 1 contaminate, contaminating the gyro bearings in a pressure system. This contamination can be greatly reduced by keeping a fresh, clean filter installed (preferably the clear see-through type), allowing monitoring for contamination.

The dry pneumatic pumps were not designed to operate forever. The continuous wearing of the carbon vanes and rotor provide a lubricant for self-lubrication, compensating for the friction developed. This wear factor gives these pumps a very definite life span. The wear cannot be stopped, but we can increase or decrease it by changing the operation perimeters of the pump. We know increasing the operating tem-

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perature of the pump will increase its wear. A logical solution would be to: cool the environment the pump is operating in. The aircraft designers did not exactly have the pneumatic pumps foremost in their minds when they designed their engine compartment. These pumps are often located in an area on the engine that receives very little of the cooling air being baffled through the engine nacelle. In these cases the addition of a pneumatic pump cooling shroud/flange kit will cool the pump closer to its designed operating temperature. This works great when the higher operating temperature is a result of the environment the pump is operating in. However, if the higher temperature is the result of a faulty system, the addition of a cooling shroud may have an adverse effect on the pump's wear. The clearances within the pump are designed for operation within a particular temperature range. If the pump goes above these operating perimeters, the parts of the pump will expand causing excessive friction and additional wear. Cooling the exterior of a pump will tend to shrink the case, amplifying the friction and this condition. Use of the pneumatic pump cooling kit should be limited to those aircraft with insufficient exterior pump cooling.

While aircraft owners tend to have a dislike for the cost and downtime required for periodic inspections, when the situation presents itself, they have a greater dislike for failures resulting in unscheduled downtime. In the interest of aviation safety and a lower operating expense, any part of an aircraft with a definite wear factor or life span should be periodically tested or inspected. Like many aircraft systems, for the gyro instrument pneumatic system, any timely inspection or testing would be better than the present "none."

In my opinion the aircraft gyro instrument pneumatic system is one of those systems that would warrant periodic inspection and testing. All aircraft instruments are less than perfect when they are new or freshly overhauled. From the time they are manufactured or overhauled their condition starts on a declining slide until failure occurs. Pneumatic pumps and other components in the system have the same declining perimeters. This decline cannot be stopped. With proper testing and inspection we can determine with some accuracy when a failure is about to occur, and we can repair or replace them before the untimely failure.

We have the technology and experience to prevent these premature failures with preventative maintenance, periodic testing and inspection. Putting this into motion, there is no doubt we could be approaching zero failure of all components in these gyro instrument pneumatic systems. In the interest of aviation safety "approaching zero failure" is much less costly and safer than the alternative.

• Require Everyone Working on or Operating These Pneumatic Systems to Have Some Education on These Systems

Most failures in these pneumatic systems can be traced back to someone's lack of knowledge about the system. Education should have top priority for those personnel performing maintenance or operating them. Several years ago, Airborne, the major manufacturer of aircraft gyro instrument and de-ice pneumatic systems (with the exception of the gyro instruments) came to the realization they were having far too many unwanted pump failures. Looking into the matter they found poor maintenance or improper operation caused most of their pump failures. They also determined this was primarily caused by personnel not knowing the fundamentals of the systems. They took on the monumental task of educating the entire aviation industry on the operation and maintenance of their pneumatic systems. This effort has been a great boost in extending the life of their system components. This unsolicited effort by Airborne has undoubtedly improved aviation safety, and possibly saved several lives. Today we have many OEMs, PMA suppliers, and other interested parties that have printed material and training available on these systems.

Aerotech Components Inc. was founded in 1993 and joined by its current CEO, Ralph G. Heysek. While being employed for 17 years with Airborne, an air pump manufacturer that had dominated the aviation market from the early 1960s, Heysek became an expert in aircraft pneumatic systems through his FAA certified seminars and constant contact with customers, providing them with solutions to all their aircraft pneumatic system problems. Heysek was and still is one of the major players in the education of the aviation industry on gyro instrument pneumatic system. If there is anyone who knows more about these systems I have yet to meet them. Without obligation he will answer your questions on these systems. Check out his website www.aerotechcomponents.com

• Eliminate The Use of Teflon Tape Anywhere in the System

Teflon tape is definitely a "no–no" in these systems. Visit any manufacturer or FAA Certified Repair Station who's manufacturing or overhauling dry pneumatic pumps, and they will very quickly point out the many pump failures caused by pumps trying to digest Teflon tape or other foreign matter.

• Periodic Inspection and Testing

Periodic inspection and testing is the only method available to eliminate unscheduled maintenance and failures.

Taking into consideration that most failures in these pneumatic systems were not due to the products involved, we see the problems are caused by systems not operating within their designed perimeters. Airborne has taken the initiative of providing the aviation industry test equipment and procedures for testing their pneumatic dry air systems. This equipment is compatible with most pneumatic dry air systems. Contact Airborne for details.

Many of the OEM and PMA dry air pumps on the market today have methods of inspecting for brush wear. Periodic use of this inspection method will allow us the advantage of changing the pump before excessive wear will cause pump failure.

Timely inspection and testing of the gyro instruments will eliminate untimely failures. Seldom, if ever, do these instruments fail without giving some prior indication.

• Add an In-line Filter In Vacuum System

Install a pneumatic inline filter in the air line connecting the gyro instruments to the inlet port of the vacuum pump—preferably near the inlet port of the pneumatic pump, and preferably the clear see through type. This allows monitoring for contamination.

Monitor and make timely replacement of all filters in the system.

One source for more information on the clear see through type filter would be Aerotech Components Inc., (702) 329-4028.

• Add An Intake Tube

The addition of a vent tube from the intake of the vacuum pump to the exterior of the engine nacelle—will eliminate the positive pressure in the engine nacelle from the inlet port of the pump. With this addition the pressure at the inlet port of the pump and the pressure on the interior of the aircraft will be approximately the same and there will be no reverse airflow in case of a failed pump.

• Use Extreme Care in Handling Pumps, Instruments and All System Components Before and During Installation or Replacement

The carbon parts of the pump and the bearings in the gyro instruments can be easily damaged if not handled properly. Keep all air inlet and outlet ports covered prior to installation and use extreme care to prevent any contamination from entering these ports during installation.

With every new or overhauled pump RAPCO Inc. includes a dry air pump removal and installation instructions pamphlet containing the basic information or knowledge one should have prior to the removal or installation of a dry air pump. If you do not have one they are available from RAPCO Inc.

• Use Extreme Care to Keep Any Liquids From the Drive Shaft of the Pump

The pump's drive shaft seal is primarily a dust seal and will not prevent liquids from entering the pump. When performing engine maintenance, degreasing or the use of any liquids on the engine in the area of the dry air pump be sure to keep the pump covered.

• Make Sure All Air Lines are Clean and in Proper Condition Prior to Installation of System Components

Never run a pneumatic pump system with any part of the systems not installed or open lines. Make sure there is no foreign matter in any part of the system's air passage. Be sure to clean the system after a pump failure. Inspect and replace any old or damaged hoses. Remember, hoses are a lot cheaper than pumps. ❑