What every technician should know about turbine fuel contamination

Fuel contamination in jet fuel can lead to many problems. Most of the time, contamination is easy to control by changing filters and adhering to maintenance procedures which stress cleanliness.

Unfortunately, most maintenance personnel aren't aware of the fact that fuel systems can be contaminated by microorganisms, and this contamination is difficult to control. It cannot be seen by the naked eye, and once it contaminates the aircraft's fuel system it will continue to exist unless it's controlled.

The following Q & A, offered by Hammonds Fuel Additives Inc., describes the effects of microorganism fuel system contamination in jet fuel and discusses methods for detecting and controlling it:

Q. What are microorganisms or bugs?

A. The scientific names for the types of organisms that live in petroleum products are Cladosporium resinae and Pseudomonas aeruginosa. The organisms are either air- or waterborne and contaminate fuel systems by entering through vents, standing water in sump bottoms, dissolved "free water," or trash incurred during transport or delivery. They grow at incredible rates with some varieties having the ability to double in size every 20 minutes.

Q. What do these microorganisms do?

A. These slimy bugs live and multiply in the fuel/water interface. They actually exist in the water and feed off the hydrocarbons in the fuel. They are referred to as "hydrocarbon utilizing microorganisms." As they grow, they form mats that are dark in color and appear gel-like. Their waste produces water, sludge, acids, and other harmful byproducts. Microorganisms will also consume rubber gaskets, O-rings, hoses, or tank linings and coatings.

Q. How do I know I have microorganism contamination?

A. The signs of microbial growth can vary. Some of the obvious signs are clogged filters, loss of engine power due to fuel starvation, plugged lines, contamination on tank bottoms, fuel with a sulphur smell and tank access lids with green or brown slimy formations. A more definite appraisal may be made with the use of a microbe detector kit.

A microbe detection kit can help make a definite appraisal of whether or not fuel is contaminated. Above are two detection kits currently available.

Q. Why do I need to control microbes in fuel systems?

A. A sterile fuel system is one with lower maintenance costs. That translates to reduced equipment disruptions or downtime due to fuel system complications. The elimination of bugs in both storage and equipment tanks will also reduce the chances of fuel tank damage due to corrosion from the microorganisms' acid waste products.

Q. Isn't good fuel management and "proper housekeeping" enough to avoid problems?

A. The highest standards of housekeeping will not ensure the absence of microbial infestations and associated problems. Microbial spores can exist in a dormant stage for extended periods of time waiting for trace amounts of water or improved growing conditions.

Q. What should I do if I find I have a problem?

A. An additive is recommended (such as Hammonds Biobor® JF) to exterminate the infestation. The remains might appear as coffee grounds in the bottom of the fuel tank.

For more information on microorganism detection, contact the following:

Hammonds Fuel Additives Inc.
P.O. Box 38114-407
Houston, TX 77238

Aviation Laboratories
5401 Mitcheldale #B6
Houston, TX 77092

AMT *November/December 1994*

The importance of cleanliness in hydraulic maintenance

A little attention to a clean work environment can mean the difference between failure and success

By Greg Napert

Hydraulic systems require relatively little maintenance on today's aircraft. For the most part, hydraulic fluids are capable of withstanding a wide range of operating temperatures, and the loads placed upon the systems are relatively light.

So it's not in operation that these systems usually break down; instead, it's more often than not that foreign substances are unwittingly introduced during scheduled maintenance. And it's the introduction of these contaminants that work on the system and degrade it.

"Ninety-nine percent of the key to hydraulic maintenance is cleanliness," says Paul Finefrock, president of Thunderbird Accessories Inc., in Bethany, OK. "When you work on a hydraulic component, line, or whatever, you've got to treat the area like a surgical operating room.

"Cap all ends immediately, clean all your tools, and the surrounding area, and do your work in a clean environment.

"And don't leave hydraulic fluid uncovered in an open container. Every bit of dust in the air will stick to the surface of the fluid, and the surface will begin to oxidize."

Joe Lundquist of Pall Corp., a manufacturer of hydraulic filtration systems, agrees. "We've conducted tests and have found that with hyperfine filtration (below 1 micron) bearings just don't wear out. This ties in the need for better filtration. And it's more important especially with engines that they are trying to get more and more horsepower out of. We also find that better filtration can extend the life of the oil itself, the change intervals. We have been doing some work in this area on helicopters and have found our programs to be very successful.

"If we can improve the cleanliness of the hydraulic system, you're looking at such things as improved component life and a savings on hydraulic fluid where instead of having to change it occasionally, you can get indefinite life out of the fluid.

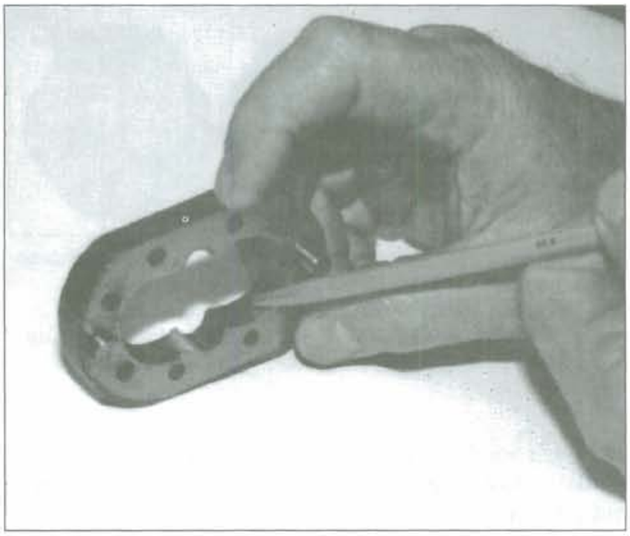
"We're finding also that if you properly maintain a fluid by removing water (with vacuum distillation purification units), filtering particulate contamination, and you don't stress it by shearing it or subjecting it to high temperatures, the fluid will not oxidize and will remain stabile."

Cleanliness is absolutely essential in a hydraulic pump due to very tight clearances of the pump mechanism.

Lundquist says Pall likes to recommend that maintenance facilities beginning a program like this use a company that does spectrometric oil analysis. He suggests monitoring the oil closely until they are comfortable with how long they should use hydraulic fluid and how often they should filter it.

Finefrock says that hydraulic components have become outrageously expensive; you're talking between $14,000 and $15,000 for a new Skydrol® type pump.

The criticality of proper cleanliness and proper clearances in a pump are exemplified by the fact that if you install gears in a pump that produce a clearance of over one and one-half thousandths, the pump won't pump fluid.



Serrations in the surface of the pump body indicate excessive contamination of the hydraulic fluid in this pump.

Source of contamination

Finefrock says that you need to be aware of contamination from sources like rubber gaskets and seals. A piece of rubber, although the reservoir strainer will take it out most of the time, can take out the hydraulic pump very quickly. Because there's only between .001 to .002 clearance in the pump, a piece of rubber can jam between the gears and seize the pump, which will shear the shaft. We've also seen where rubber works its way between the flat face of the gear and the housing and builds until it pushes the opposite side against the housing and causes metal to metal contact. And this results in the gear seizing.

Most contamination is primarily metal as a result of normal wear and tear of components in the hydraulic system, however, and this slowly wears away at the gears and bearings in the hydraulic pump.

Hydraulic fluid will oxidize and turn sticky where it's exposed to the air. And if you have a suction leak and cause foaming in the reservoir, it will cause the hydraulic fluid to break down.

You've got to remember also that when you attach the hydraulic mule to the aircraft to cycle the gear or other hydraulic systems for maintenance purposes, you are changing out the fluid with the fluid in the mule at that time. You need to be aware of this and make sure that your fluid in the mule is fresh, clean, and properly filtered preferably with a 1-micron or better filter.

Some maintenance shops will go through many aircraft maintenance checks with their mule and not even change the fluid in the mule once. Also, you've got to be aware that if you use the mule to purge a system and filter contaminated hydraulic fluid, you should clean the mule and change the fluid on the mule before using it on another aircraft.

In fact, the mule is a good way to filter the hydraulic system occasionally if it has a good filter on it.

We've also seen some of the rubber hoses in hydraulic systems break down after a period of time and begin contaminating the system. Solid lines aren't a problem. But rubber/synthetic hoses become brittle after a while and small chunks of the liner break off and contaminate the system. That's why it's important to change the hoses out at the slightest sign of them becoming brittle or damaged. There are too many aircraft flying around with 20-year-old rubber hoses that have never been changed.

Inadequate filtration systems

Finefrock says that, "one of the major problems with aircraft hydraulic systems is that there is no real good filter or filtration system on them. Basically, one reservoir services the entire aircraft. And the only filter on the system is a strainer that is on the inlet side of the pump This is a fairly coarse mesh strainer, and I swear to God that coffee grounds will go through. All it will take out is some large particle, like two microns.

"A really good idea for protecting your hydraulic system is to install a suction side filter on the aircraft that can filter particles down to 1 micron. As a matter of fact, I've installed one on mine. All you need to do is install a filter housing that's equipped with a bypass, and a flow gauge to monitor the condition of the filter (you'll need this so that you don't cause cavitation of the pump), and a filter, and you'll protect the pump from ever receiving any kind of contamination. We highly recommend putting this on the suction side of the pump between the reservoir and the pump. You could put it on the return side before the fluid returns to the tank, but then you wouldn't prevent contamination that's introduced into the reservoir from getting to the pump. Basically, you're installing the filter to protect the pump, which is the most critical part of the system and most susceptible to damage."

Finefrock continues, "Kits are available for this purpose from various automotive or commercial sources for a relatively low cost, and a field approval should be relatively easy to get.

"Some of our customers install a temporary filter to run on the system after finding contamination or after a component failure. They'll then run the system for six to eight hours with the filter on to clean out the hydraulic oil and then remove it for flight.

"Another option, of course, is to use a mule with a good filter on it and to purge the system with a mule. But you need to do it right. You need to put it up on jacks and run the gear up and down and cycle all of the hydraulics to assure moving all of the oil through the system.

"In any case, you really need a filter that is capable of removing all contamination down to a 1 micron size. With this level of filtration, the system will operate properly, you won't have any problems, you won't break pumps, and you won't be sending them back to us for warranty," explains Finefrock.

Some product improvements

Finefrock says that one of the changes they have made to accommodate the inevitable introduction of contaminates to the hydraulic system is a to replace the bronze bearings on certain hydraulic pumps with needle-type bearings. Contamination in the hydraulic fluid causes conventional bronze bearings to elongate. The result is too much play and eventually the gears begin binding on the gear faces until it shears the drive shaft.

The modification involves boring out the existing brass bushing, replacing it with an oversized aluminum bushing, and then pressing in a needle bearing.

"The cost of performing this modification on an 105HBG pump, for example, is approximately $1,100, where buying a new one is $5,600," he says.

"Additionally, we've found the need to increase the diameter of the shear section of the drive for this same pump. We feel that it was originally designed to fail at too low a pressure.

"A discovery that we made, quite by accident, is that shafts are often shearing due to malfunctioning accumulators. What happens is as a result of the check valve in the accumulator sticking, the accumulator bangs in rapid succession, and this hammers at the drive shaft and eventually shears it. This happened to us once on our test bench.

"It really doesn't take much hammering either. It only has to happen one time and it cracks the shaft, or it can also shear the key that engages the driven gear of the pump.

"When we receive a pump in for overhaul that has a sheared shaft or key, we now call the customer immediately and tell them that they may have a problem with the accumulator," says Finefrock.

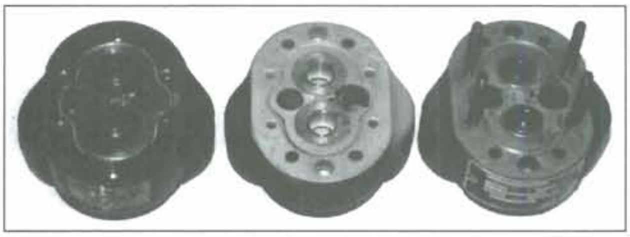
He explains that if the accumulator isn't working, it can also blow the seal out of the intake side of the pump. "It happens because you shut the engine down and the back pressure forces its way through the gears and puts reverse pressure on the seal," he says.

"Many times technicians assume that it's a problem with the pump, but if you blow out a seal, it's usually a problem with the accumulator.

"If the seal is blown, you have to take the pump apart to replace the seal, which means you have to put the pump back on a test bench to make sure it works.

"When we see this, we immediately alert the maintenance facility that they need to repair the accumulator."

Finefrock says that another way to damage a pump is to fail to purge the air out of the hydraulic systems after performing maintenance on them. If you don't purge the system and get the air out of it, the pump cavitates and then surges, and this frequently shears the drive, he explains.



Modified pump for the purpose of making it more resistant to wear due to contamination involves replacing the original brass bearing with a needle bearing. First, the brass bearing is machined out (left), an aluminum bushing is installed (middle), and the needle bearings (right) are installed.

"What we do is use a cap that is adapted with an air regulator and gauge on it. We attach it to the reservoir and put 2 1/2 pounds of pressure on it. We then take the outlet line from the installed pump and pull the prop through by hand or motor it to turn the pump until we have clear fluid coming out of the discharge line, no bubbles. Sometimes it takes a gallon or 2, but it's worth it to save the pump. You'll never have a problem if you do that. Directions for this are in most aircraft maintenance manuals," he says.

"We had one company put three pumps on down in Georgia that had air in the system, and he called accusing us of problems with the pumps. We told him if he read the directions, that he would purge the system and that was the problem."

More frequent maintenance please

Finefrock says he's observed that too many people are trying to make their accessories last to TBO before overhauling them. "We never use to do that. We use to overhaul all of our accessories at 50 percent of TBO, and we never had any problems. And I guarantee that it costs very little to have a unit that's in good condition overhauled, compared to replacing something that's broken, especially where TBOs on engines are being extended longer and longer. People are expecting the accessories to last as long as these engines, and the accessories rarely went to TBO when they were much lower.

"Not to mention that if you wait till something in the hydraulic system fails, there's a good chance that you'll get contamination from the parts that have failed, such as metallic chips, gaskets, shavings, etc., and end up damaging other components in the system. At the very minimum, you'll have to flush the system thoroughly."
September/October 1994

Auto pilot INOP: Oh no!

Key to troubleshooting autopilots is in asking the right questions

By Jim Sparks

Automatic Flight Control Systems (AFCS) are categorized by how many axes of flight they can control: The single axis autopilot, found in many small aircraft, is a device for holding the wings level. Dual axis autopilots can sometimes coordinate aileron and rudder, or, in other systems dual axis will work with an on-board "yaw damper" to provide pitch and roll control. Many systems today are three-axis, and integrate pitch, roll, and yaw.

Isolating malfunctions

When malfunctions in the AFCS exist, it becomes necessary to associate the fault with a specific axis of flight:

The pitch axis is the vertical mode and control information supplied from air data systems, radio navigation, vertical navigation computers, or flight management systems. Autopilot response to commands from the vertical mode can be made by elevator deflection, changing the angle of attack of the horizontal stabilizer or even by moving trim tabs. If the flight control cannot respond to a specific condition, the autopilot can interpret this as a failure.

A common malfunction in the vertical mode of auto flight is "porpoising." This is defined as "a low frequency oscillation in the pitch axis." The usual image of a porpoise is jumping in and out of water and not maintaining a level path. There are various situations that can result in porpoising. For instance, if cables are used to connect the autopilot servo motor to the elevator system and cable tensions are not correct, overcontrol is probable and the aircraft will porpoise. Also, several types of aircraft make pitch changes by changing the horizontal stabilizer angle of attack. Most use an electric motor for this. If the motor operates too slowly, the autopilot will always be lagging and this will cause porpoising. In an attempt to prevent this, manufacturers sometimes incorporate "brakes" to ensure an immediate stop and prevent overtravel.

However, the brake is often manufactured from carbon. With wear the carbon dust accumulates between the friction disc and rotor. This dust works as a lubricant and significantly reduces the stopping power of the brake. The result is stabilizer overrun and again, porpoising.

Not all of these low frequency oscillations can be blamed on mechanical components, though. Faulty information supplied to the auto flight system may result in the autopilot commanding the porpoise.

The information driving the autopilot is available from one of two sources: the pilot using a manual autopilot input, or more often, a "flight guidance" or "flight director system."

Flight directors will compile all flight data available and summarize it using priorities issued by the pilot. The result is a pictorial display using "V" bars or "cross-hair pointers," typically on the attitude indicator. The pilot can manually fly the aircraft using this display or can allow the flight director to communicate directly with the autopilot.

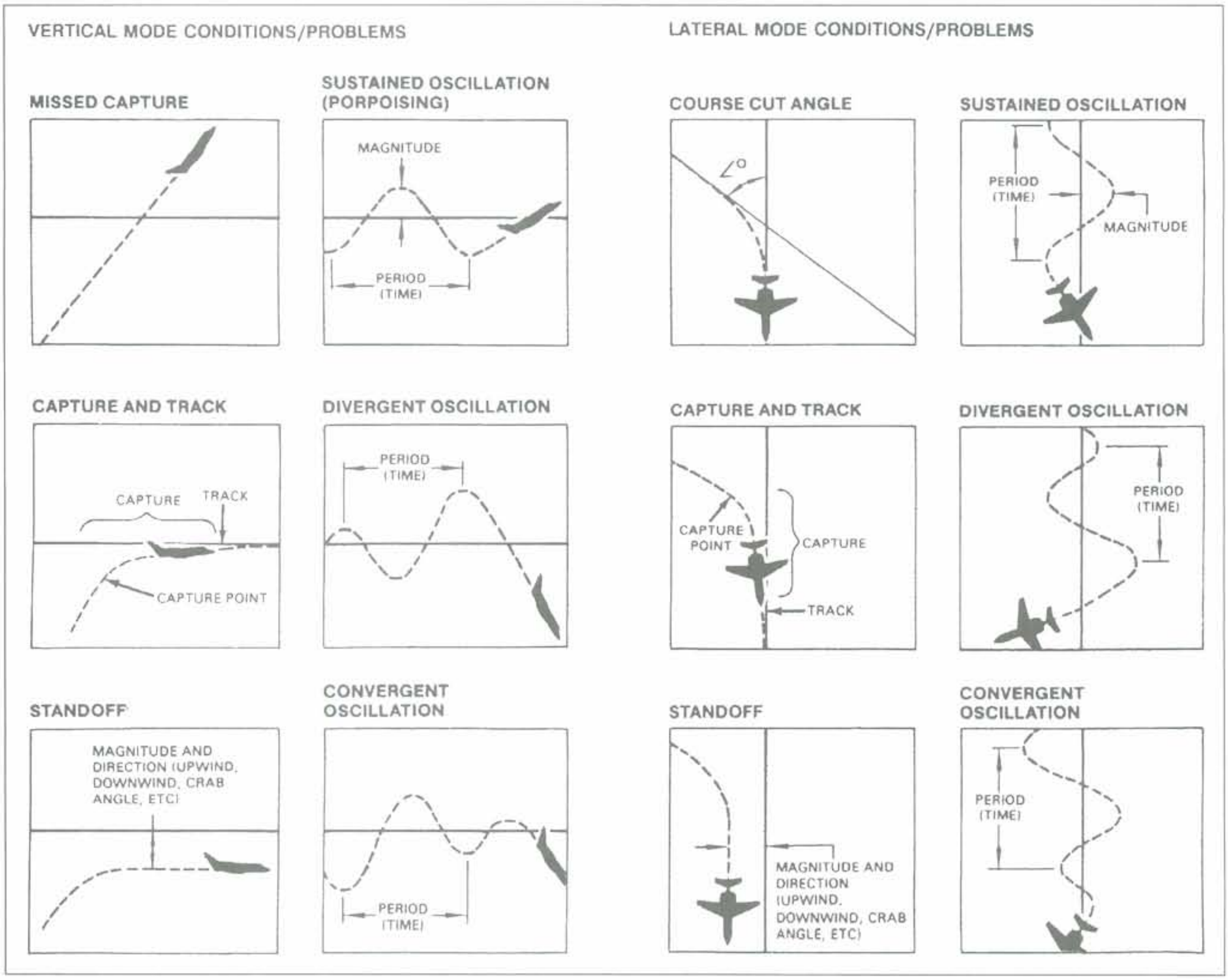
By interrupting this communication or by switching the autopilot to a second flight director, the input data problems can be isolated. If the porpoising stops with an alternate flight guidance system supplying the information, a high likelihood is that the problem is with the primary flight director or one of its information providers.

Operation of the autopilot in "basic mode" is usually a good place to start fault isolation. "Basic mode" is the condition in which the autopilot will function without commands from the flight guidance system. Pitch hold and vertical speed hold are the most common "basic vertical modes." If the autopilot is engaged without selecting a flight director mode, the autopilot will most likely hold the aircraft just as it was when activated.

When a porpoising problem is encountered, you should determine if the porpoising is also occurring with the autopilot in its basic mode. If it is, then the problem may be associated with the basic mode sensors, air data, attitude reference, or with the autopilot to airframe interface. If the porpoising does not occur in the basic mode but only with ALTitude Hold engaged, then the sensors that supply the aircraft altitude reference and the altitude selection may be a good beginning in the fault isolation process.

Find out how the system performs with other vertical modes, which are: air speed hold, mach hold, vertical speed hold, and approach. If the porpoising disappears during approach with the automatic flight system receiving its information from a navigation receiver vs. an air data computer, common sense dictates that you check the air data systems.

Other common vertical mode discrepancies include "pumping," a low frequency control wheel movement back and forth, "stick bump," where controls give a quick



moderate movement with little aircraft reaction, and "stick buzz," a high frequency small movement of the control wheels with no aircraft response.

Lateral mode auto flight discrepancies can also prove quite challenging. The basic lateral mode is "bank hold," or in some cases "heading hold." These modes are if the aircraft is presently making a turn and the auto pilot is engaged the aircraft will continue to turn until the autoflight system receives a command that has priority over the basic mode. Other common lateral modes include HeaDinG, NAVigation, and APProach.

The HeaDinG mode will use information provided from the Horizontal Situation Indicator. The actual aircraft heading is compared to a heading reference selector. Anytime the HDG mode is activated and actual aircraft heading does not agree with selected heading, the AFCS will command a bank to the selected heading. The bank angle is preprogrammed and can be automatically altered, depending on aircraft speed or altitude. A failure of the directional sensing system will usually prevent the autopilot from being engaged. The directional system also can provide rate of turn information.

For the NAVigation mode to function a navigation receiver has to be operational. When maneuvering with VOR (very high frequency Omni directional Receiver) information, not only does the NAV receiver have to be appropriately tuned, but a course also has to be selected for the specific station. The VOR station transmits omni directional signals in a full 330-degree arc. Each degree of the arc is referred to as a VOR Radial.

The Approach function operates in a similar manner as NAV. The gain or system responsiveness might be modified with the aircraft in a landing configuration since airspeed is usually much lower than during cruise. This means the autoflight system will have to use greater flight control deflections.

This sensitivity adjustment is made using airspeed information or radio altitude. Localizer gain programming can also be activated by tuning a NAV receiver to an Instrument Landing System frequency. Malfunctions in the gain programming can cause problems such as oscillations. The autoflight system continually over-corrects and the aircraft cannot properly track the NAV signal.

The yaw axis is usually controlled by a rudder autopilot servo or yaw damper. This function is used to ensure turn coordination and to prevent slip. During high speed flight, if airflow over an outboard wing is disrupted, a wing dip could result. If uncorrected, this asymmetric airflow could result in a dutch roll. A yaw damper can provide immediate rudder response to prevent the dutch roll tendency.

The primary source of information for rudder control is a yaw sensing gyro. Some systems will use the normal inertial reference system for this information. Other manufacturers will use an independent yaw gyro. Yaw damper authority, or the amount of rudder deflection, can be regulated by airspeed. In many cases discrepancies with the yaw damper can be related to airframe or engine problems. If a flap system is misrigged and one flap is extended slightly, this will cause an asymmetry in wing airflow and the yaw damper will have to compensate. In some systems a continuous yaw damp command signal will result in a yaw damp disconnect. When the yaw damper can be engaged and consistently disconnects, a good place to start troubleshooting is with checking flight control rigging, engine alignment or asymmetric thrust, and even possible fuel imbalance.

In most AFCS the yaw damper can be engaged without the autopilot, but the autopilot will not engage without the yaw damper.

A good guideline to follow when faced with an autoflight discrepancy is based on two rules:

1. Before taking any action, determine conditions when the problem exists.
2. Get the flight crew to give a complete description of the problem.

Asking questions

There are many questions to be asked for accurate diagnosis. Here are a few to keep in mind:

- Are any fault annunciators illuminated?
- Which flight axis is experiencing the problem?
- In what modes or conditions does the problem occur?
- Is the problem related to flaps, landing gear, or airbrakes?
- Does it occur only at certain engine power setting?
- Is airspeed a factor?
- Is altitude a factor?
- Does the problem occur in more than one flight guidance mode?
- Could the problem occur with a specific sequence of mode selection?
- Do only certain radio frequency selections give the problem?
- Does the problem only occur when using a radio transmitter?
- Does the weather radar have an effect?

Remember, even the configuration of electrical power sources (alternators, generators, inverters) may introduce malfunctions.

Built in test equipment

In AFCS using digital technology it is common to find Built In Test Equipment BITE. This is used to continually monitor the AFCS and record any faults. This memory can then be accessed and the displayed fault code translated to locate the failure. These "flight fault" memories, in many cases, can be erased by removing power from the system. It is essential to inform the flight crew to leave the system powered so any fault codes can be recovered. Prior to troubleshooting any AFCS discrepancy and after a thorough crew debrief, it's beneficial to obtain an operating manual for the specific installation and read about how it's really supposed to work. The airframe manufacturer's maintenance manuals, *Airline Transport Association*—Chapter 22 "Auto Flight" and Chapter 34 "Navigation"—can add depth to the text of the operating description. This sometimes is sufficient to make a knowledgeable judgment as to faulty components. If the problem can't be diagnosed at this level, it may be necessary to get avionic manufacturers' manuals and installation diagrams. *July/August 1994*

Jim Sparks is an instructor for FlightSafety International in Little Rock, AR. He has over 13 years of maintenance instruction and holds an A&P and FCC certificate.

Large aircraft air conditioning

An overview

By Jim Benson

To transport passengers and crews from point A to point B comfortably, an aircraft's environment must be designed to satisfy any demands that will be encountered during a flight. To do this air inside the cabin is modified with a process called air conditioning.

Air conditioning is the process of treating air so as to control simultaneously its temperature, humidity, cleanliness, and distribution.

The Garrett Corporation, a division of Allied Signal of Phoenix, AZ, furnishes about 90 percent of environmental systems for the aircraft produced in the free world, and today, virtually all modern commercial aircraft use an air cycle system called an air-conditioning pack (short for package). The basic supply of air for an air-conditioning pack while in flight comes from the aircraft's engines. When parked, it comes from a built-in auxiliary power unit called an APU.

The air is commonly referred to as pneumatic air and is bled from the compressor sections of the engines or APU. Newer air-conditioning systems have been designed to run so efficiently they use less of this pneumatic air source, thereby, allowing more air to be used by the engines or by smaller more efficient APUs.

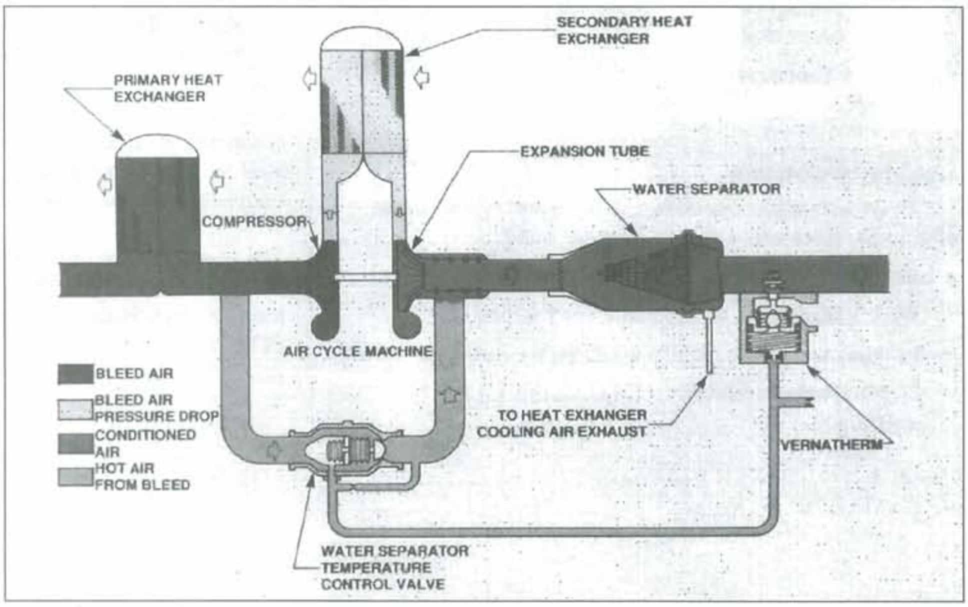
Improvements in the design and operation of air-conditioning systems have led to less maintenance, higher efficiency, and better troubleshooting. Computers not only monitor and control the operation but store fault information and data for current and future interrogation to help keep the system running at peak performance. This translates directly to lower maintenance and fuel expenses.

The air-conditioning pack

A basic air-conditioning pack is made up of a pack flow-control valve, two heat exchangers, a bypass valve, anti-ice valve, air cycle machine, and a water separator. The air is typically bled from the engine at about 45 pounds of pressure and 400°F. The bleed air enters the pack through the flow-control shut-off valve. This valve can be a combination shut-off and flow-control valve, or separate shut-off and flow-control valve. Its purpose is to start or stop the pack and control the volume of air based on the area to be heated or cooled.

The flow-control valve is basically a venturi with a valve. When closed, it can act as a shut-off valve and when open it is modulated to control the flow of air. If we measure the air pressure at either end of the venturi and compare it to the air pressure at the throat, we find that the air pressure at the throat of the venturi is lower than air pressure at either end.

This difference in pressure is affected by the amount of air flowing through it, so the greater the flow of air, the greater the difference in pressure. This difference in pressure is used to control the movement of the valve, thus controlling the amount of air flowing to the air-conditioning pack.



Air-cycle air conditioner