

It's Freezing Hot!

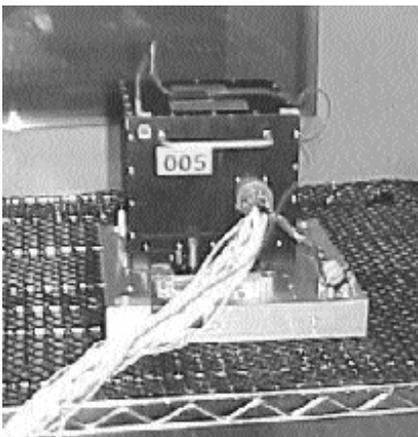
Dealing with Avionics and Temperature Extremes

BY JAMES WYNBRANDT

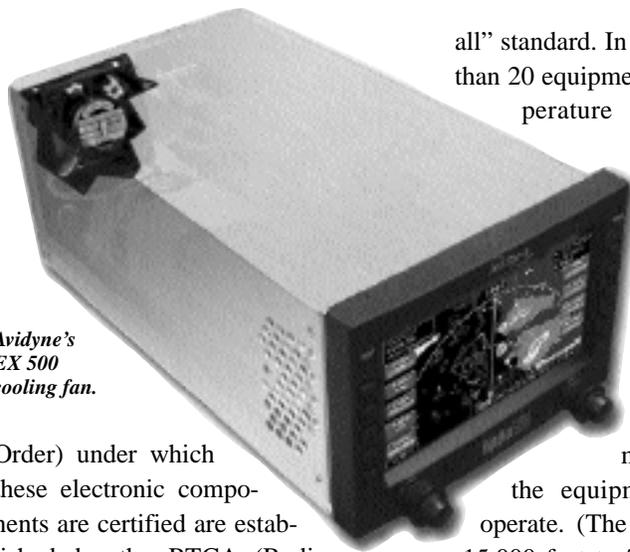
You don't work very well when you're overheated or chilled to the bone. As it turns out, neither do most of the components you work on. Excessive temperatures—those above or below the limits the equipment is designed to operate within—can cause problems from reduced reliability and service life to outright failure. So whether installing, repairing or maintaining avionics, technicians need to be aware of the potential for exposure to temperature extremes, the problems they can cause, and how to prevent them.

Operational Requirements

All avionics are designed to work within an envelope of temperatures they can reasonably be expected to encounter while in operation or on the ground. The TSO (Technical Standard



An Inertial Reference Unit (IRU) in a temperature test chamber at Honeywell.



Avidyne's EX 500 cooling fan.

Order) under which these electronic components are certified are established by the RTCA (Radio Technical Commission for Aeronautics). This non-profit organization, comprising over 270 U.S. and foreign government agencies, businesses and academic organizations, acts as a consultant and technical advisor to the FAA. Document RTCA/DO160D, "Environmental Conditions and Test Procedures for Airborne Equipment," sets the Minimum Operations Performance Standards, or MOPS, for temperature and altitude ranges at which civilian avionics must function. (Other environmental conditions covered by DO160D include pressure, humidity, radio frequency susceptibility, electrostatic discharge, lightning, vibration and power input.) Given the range of avionics and aircraft in which they're installed, this is not a "one-size-fits-

all" standard. In fact, there are no less than 20 equipment categories for temperature MOPS. These are based on a combination of whether the installation is in a pressurized or non-pressurized location, whether the location is temperature-controlled or not, and the maximum altitude at which the equipment is expected to operate. (The altitudes range from 15,000 feet to 70,000 feet, the latter intended for equipment used aboard pilotless drones.) Thus, avionics designed for external installation on a pressurized aircraft will have to meet more stringent TSO for temperature than one designed for installation inside the cockpit of a non-pressurized aircraft.

There are also MOPS that cover additional temperature parameters: short-time operating high temperature (the highest temp equipment can be exposed too for a short duration); ground survival temperatures (highest and lowest temps the equipment can survive while sitting unused on the ground); and temperature variation (the rate of temperature change the equipment must be able to handle).

If a technician has any question about the category or operating param-

eters of a given unit, this information is specified in the Environmental Qualification Form (EQF) packed with all factory-fresh airborne equipment (as mandated by DO-160D). The EQF also contains descriptions (if applicable) of performance parameters the equipment meets that are not called for in the TSO under which it's certified. For example, if the equipment is certified to work at temperatures above or below the MOPS, the EQF will state this.

The Real World

Most avionics installed in the cockpits of general aviation aircraft are certified to operate from a low temperature of minus 15 or minus 20 degrees Celsius (5 or minus 4 degrees Fahrenheit) to a high of 55 or 70 degrees Celsius (131 to 158 degrees Fahrenheit). Ground survival temperature range from minus 55 Celsius (-67 degrees Fahrenheit) to 85 degrees Celsius (185 degrees Fahrenheit) for almost all categories. This provides a sufficient temperature envelope for most operations. But avionics still encounter temperatures capable of affecting their operation or lifespan.

"Up in Barrow, Alaska, it gets down to minus 50, 60 degrees Fahrenheit. In Phoenix and Las Vegas, the cockpit can get over 150 degrees," notes Matt Fowle of Mid-Continent Instruments West in Van Nuys, Calif. Mid-Continent, which overhauls and supplies avionics and instruments, has many customers who operate in extreme environments. One requirement for servicing this market: Rigorous testing. Mid-Continent uses environmental chambers to subject equipment to real world extremes.

"We can cycle the equipment in the chambers," said Fowle. "We can program in minus 50 degrees Fahrenheit,

hold it for 10 minutes, then increase it a degree a minute until it's 160 degrees, then hold it for 10 minutes. We don't do that with every single instrument, and it's not required, but if you don't test them within range, how do you know they'll operate?"

Fowle recommends an environmental chamber for any shop doing work on avionics used in extreme temperatures or other extraordinary conditions. End-users routinely operating in such extreme conditions may need to have equipment customized, a service Mid-Continent has developed a reputation for providing.

"You have to hand-pick special components to get them to work that way," Fowle says, noting, "It does cost more to build things beyond current specs. We go through quite rigorous testing for after-market customers."

Cold Facts

While the effects of low temperatures on powerplants and mechanical parts are widely recognized, the cold facts about avionics are less well known. But talk to technicians who regularly encounter these conditions and you'll hear a litany of potential areas for squawks: Encoders may not operate at temperatures below TSO specs. The LED screens on modern avionics may not light up. Remotely mounted gyros may fail to erect. Maintenance personnel need to be ready to take preventive steps.

"I think people have to realize even if you get heat in the cockpit for the pilots benefit, you have to remember where remote gyros are located and heat them," said Aaron Talbot, director of maintenance at Frontier Flying Service in Fairbanks, Alaska. Cold temperatures thicken the bearings' lubrication fluid, whether grease or oil. "We sometimes have had our air-

planes rigged with portable car heaters permanently mounted in avionics spaces."

A silicone pad resistance heater can also be attached to the gyro mounting to provide preheat. Even panel-mounted gyros can fail in flight in extreme cold, should the aircraft lose heat. So heaters can become another checklist item for the avionics tech. Talbot recalls Janitrol heaters failing in the company's Chieftains while the aircraft were one-and-a-half to two hours from an airport where they could be serviced, and the gyros subsequently going belly up. "I get reports that 'a gyro flipped over on me.'" Talbot said. "It can be a fast or slow failure."

Pre-Heat and Avionics

Engine pre-heat is a known requirement for low temperatures. For avionics health, and sometimes operational

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Avidyne's EX 5000 cooling fan

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safety, cabins need preheat too. Otherwise, moisture can more easily condense in avionics, leading to corrosion, switch problems, and more immediately, sometimes an inability to see gauge indications.

"On twin turbine aircraft, the RPM gauges are critical," said Fowle, who has customers operating turboprop aircraft in Alaska, "and when the aircraft at minus 50 degrees starts heating up, it can cause the (gauge) lenses to fog, even though it meets manufacturer's specs. I learned that from the school of hard knocks."

In addition to tachometers, any instrument that contains a motor of its own, thereby generating heat, can fog up. When using preheat, it's best to use a unit that separates combustion air from the ventilating air; excess moisture contained in the combustion air will also increase corrosion.

Another lesson from the frozen north: If you're involved with aircraft operating in low temperatures, particularly operating in remote locations, outfit them for cold-weather contingencies. From its Fairbanks base, Frontier operates five Beech 1900-Cs, a 1900-D and eight Piper PA 31-350 Chieftains for both scheduled and charter service. On charter ops, which Talbot says "brings out some of the cold weather problems," aircraft may be on the ground in remote locations longer than anticipated. When dispatched on these missions, the planes carry engine covers, a portable Tesla battery cart and extra extension cords.

Even temperatures within normal ranges can cause problems when coupled with other factors. Aerospace Testing Services in Roanoke, Va., tests electronics used in aircraft, the Space Shuttle and the Hubble telescope, in addition to a variety of terrestrial applications. Company Vice President Frank Terry notes that high pressure

water hoses often used to clean business jets can get water into the sensors that control some systems, creating problems once the aircraft is underway. "A lot of things like deicing units, or angle of attack indicators have thermocouple sensors in them," Terry said. "A lot of that stuff will ice up (if water gets into the system) once you get up to altitude."

Hot Topics

While cold can play havoc with avionics, heat presents a greater threat. "Heat is by far the worst of the two conditions," said Bob Hasse, Garmin International's manager of avionics product support, "Cold generally rectifies itself in very short order." Says Richard Hopperstad of Honeywell Commercial Aviation Products, who serves on the RTCA advisory board, "Heat is what kills integrated circuits."

The major source of heat is the avionics themselves. Old tube-style amplifiers used in previous generations of avionics generated much more total heat than current units. But the way today's solid state avionics and electronics are packed and stacked in aircraft makes cooling critical. The vertical stack common to many cockpits can create what's called a chimney effect, with the rising heat potentially cooking circuitry.

Cool Solutions

In the past, some aircraft were designed to use ram air for avionics cooling. Some Cessna models, for example, ducted outside air from wing vents into the cockpit for this purpose. But that introduced moisture and particulate matter into the equipment, which was destructive in its own right. Nowadays, of course, the most common way of providing this cooling is with a cooling fan and ducts. A variety of fans, with one to five ports, allowing cooling ducts to be directed at multiple units, are available. Avionics

and electronics manufacturers often specify the amount of air flow required, expressed in cubic feet per minute (cfm). And manufacturers may either recommend or require use of a cooling fan with the installation of their product. With more customers swapping older avionics for state-of-the-art big screen boxes, the difference between "recommended" and "required" often comes up.

"We put in cooling fans with any kind of installation, even if there is no requirement," said Mark Winter, director of avionics at Swift Avionics in Phoenix. "Now they're cramming so much stuff into one (avionics) box, a cooling fan is mandatory."

Cooling issues can become a customer-relations matter for shops doing installations. The customer wants to upgrade the panel with a new MFD (multi-function display); the shop says he needs a cooling fan, but the manufacturer only "recommends" one. What to do?

"If the subject is addressed, it becomes a value added product, and it's an easy sell," says Garmin's Hasse. "It's going to be more reliable, and last longer. Selling the additional cooling is going to guarantee a better installation."

"We're big advocates of putting in cooling fans," said Steve Vold, GM and one of the owners of Aerotronics Inc., in Billings, Mont. "If you can moderate the temperatures, you're probably going to expand the longevity of your radios, or if they're older, make them last a bit longer. And that's how we approach our customer."

Temperature and Warranties

One reason beyond operational concerns of why it's important to provide adequate cooling: Warranties become void if the equipment is operated outside of the parameters it's certified for. And some of today's newer avionics have ways to record operational

parameters—including the temperatures they've been exposed to. If the temps are exceeded, the product fails, and it's returned to the manufacturer as per the warranty, the manufacturer may revoke its warranty coverage. This is the trump card Winter of Swift Avionics uses with his customers who are reticent to have a cooling fan installed along with an avionics upgrade.

"I tell them, 'OK then your warranty is void for this product. We will not honor the warranty.' If you don't tell them up front and it breaks, then it's the installer's responsibility."

So are installers skimping on cooling to save their customers money? Not from what Hasse has seen at Garmin. "People that do (installations) for a living, the shops, that's usually not a problem," he said. "Some of the homebuilt installations, that's where the issue tends to come up."

Nonetheless, the added cost of a fan can be a consideration in this economy, and one that manufacturers may increasingly consider, as Avidyne Corp., the Massachusetts-based maker of MFDs, is doing today.

"All of our new products have fans incorporated so that no external cooling is required," said Tom Harper, Avidyne's manager of marketing communications. The new products include the EX 5000 (installed in all Cirrus aircraft). "Part of that, frankly, is the cost of installation. By integrating that, that reduces the installation cost," Harper said.

Rates of Temperature Change

In all the talk of maximum and minimum operating temperatures, technicians also need to be aware of rates of temperature variation. The problem with rapid changes lies in the thermal coefficient of expansion (TCE), which defines the rate at which materials expand and contract. Ideally, all the materials in an avionics unit would

expand and contract identically in reaction to temperature changes. But they don't. And this can create operational problems when temperatures change rapidly. Concern about TCE arose about 15 years ago when avionics manufacturers migrated to leadless chip carriers.

"These work fairly well in benign temperature ranges," said Honeywell's Hopperstad, "but if you're not in that environment, you get a real significant mismatch in the way the ceramic packages and the circuit boards they're mounted to change. Unless you did a good job of matching the thermal coefficient (of the materials) you ended up with soldering problems."

Standards for TCE category MOPS are set at rates of two-, five- and 10-degrees per minute Celsius variation.

Thinking Outside the Box

Not just components can be damaged by heat. Even the equipment's face plates and displays can be damaged. Winter of Swift Aviation in Phoenix sees the problem first hand. Temperatures can easily reach 110 degrees on the tarmac in Phoenix, and Winter says the interior of an unprotected aircraft on the ground there can reach 160-170 degrees Fahrenheit. "The little LEDs in the windows will start fading out, white lines will fade out, then you have to go in and buy new face plates and cosmetic stuff," Winter says. "It can be \$700, \$800. If it's an older radio, chances are parts will be hard to come by."

Technicians can help their customers by advocating the use of cabin covers or other passive means of reducing ground exposure to temperature extremes. "We explain if (customers) are going someplace hot, unfold your sectional or WAC chart and put it in the windscreen," said Vold of Aerotronics. "That will save you 10, 20 degrees."

Troubleshooting Thermal Problems

For maintenance and repair technicians, a major challenge presented by temperature extremes is that the problems they cause can be hard to diagnose.

"Avionics connections and the rack mounted connectors can give you intermittent (problems), and condensation and moisture become a factor as things are heating up or cooling down," says Garmin's Hasse. "Sometimes these intermittents are hard to track down."

To troubleshoot these problems, technicians have to be able to recreate conditions the equipment is exposed to in operation.

"Thermal intermittents.' Those are definitely some of the toughest ones to track down," concurred Fowle at Mid-Continent. "That's when we start 'shaking and baking,' as we call it. That's the scenario we always give the technicians here. They're in a nice sheltered environment. You really, really have to try to recreate the aircraft (operating environment)." This is another time the company's environmental chambers come in handy. "It's a great tool to have when troubleshooting," Fowle said.

Conclusion

Even technicians who work in the most benign climates must recognize the equipment they work on can routinely encounter temperatures at the edges of their operational envelope. To meet customers' needs, it's imperative to find out about the temperature extremes of the environments they operate in, and be prepared to offer service and solutions accordingly. As Fowle says to Mid-Continent's customers, "I'm not just some sales boy, I want to get to know your operations, and want to make sure my instruments work in your plane." q