Carbon Monoxide In The Cockpit

Experiments at FAA's NAFEC concentrate on lightplane's muffler as a means of reducing in-flight hazard. Metal with greater heat-resistant qualities required to prevent muffler leakage and blockage, and consequent feedback into the cabin

by GARY SHENFELD

■■ Over a period of time, exhaust gases entering the cabin of a light airplane through the heater cause the pilot to accept the odor—then, later, the pilot doesn't really smell it any more. The effect of carbon monoxide on the body is cumulative, and the pilot in time can make a mistake—an accident which may be attributed to pilot error.

At the FAA's National Aviation Facilities Experimental Center at Atlantic City, N. J., Project Manager Jerry Slusher recommends that mufflers on higher compression engines be made of material more resistant to high temperatures and combustion products. Slusher has been testing engine exhausts on lightplanes for a number of years at the experimental center.

The most serious hazard occurs, Slusher says, when a hole or crack appears in the muffler wall of the exhaust system. Exhaust gases, containing carbon monoxide, can then exit to the heater and into the cabin. This only occurs when the heater is on. Another hazard occurs when the vessels and perforated tubes inside the muffler disintegrate, blocking the exhaust gas path, stopping up the openings, and causing excessive exhaust gas pressure and engine paralysis.

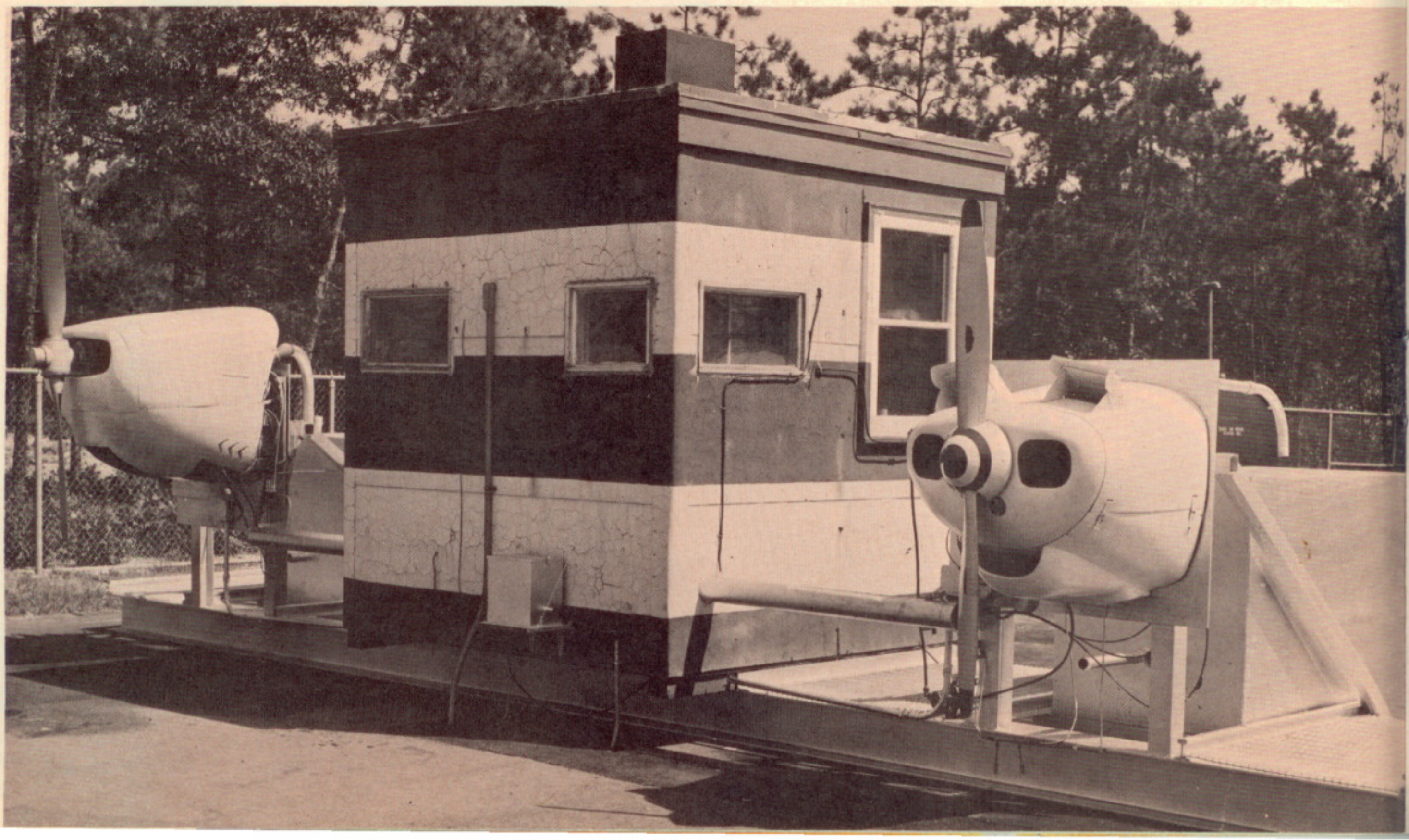
Slusher says that in studying two versions of a popular aircraft model in the last five or six years, he found more than 150 failures occurring when the perforated tube distintegrated, blocked the exhaust path, and caused engine power loss. "These are not accidents, they are incidents. We have records of 150 to 200 of them in the last four or five years.

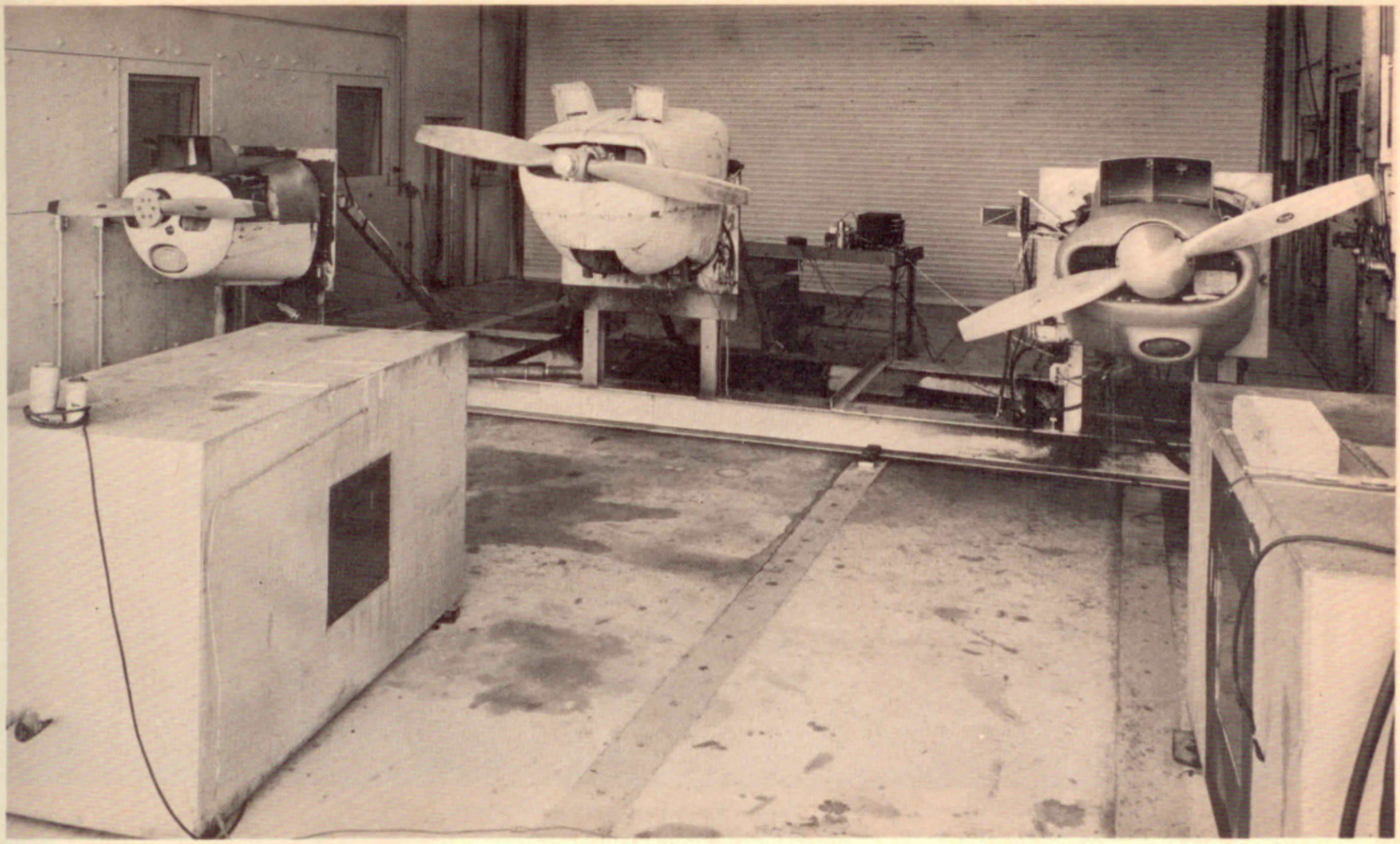
"Many nonfatal accidents that have been pilot error in the records actually could have been caused by carbon monoxide in the cabin. It affects the pilot's coordination, judgment, and his eyesight. This mistake couldn't happen today in the case of fatal accidents because blood tests are taken, but in the past some accidents blamed on pilot error should have been blamed on carbon monoxide."

The FAA first became aware of this problem in 1958. In 1962, a project through its Flight Standards Service requested that the problem be identified and something be done about it. In 1963, the FAA turned its efforts to studying the records of 13 separate accidents resulting from carbon monoxide poisoning. Also there was an accident in Indiana that focused attention on the problem.

A malfunction in the exhaust system of a light aircraft allowed carbon monoxide to enter a cabin containing a pilot and three passengers. The pilot fell asleep, and the person sitting in the copilot's seat starting flying the aircraft, Slusher explained. He got it lined up with the runway, the power reduced and so forth, when he fell unconscious and slumped over. One of the passengers in back of the cabin reached over, steering the aircraft on the final approach. On landing, the aircraft ground looped but all aboard survived.

Slusher says that as far back as 1965 his office had recommended using more substantial materials in the exhaust systems, but only in selective cases did the manufacturers comply with these findings. "After evaluation at the Allegheny and Ludlam Steel Corporation's research center, the most important conclusion reached was that the stainless steel being used was failing, in many cases, due to the high temperatures and corrosive exhaust gases. The research center recommended new metals for the exhaust system.





Three engines are set up on stands in semi-enclosed area used in later tests at NAFEC. Cabin heaters are ducted into rectangular tanks in foreground. The tanks have the same cubic volume as a small four-place airplane cabin.
FAA photos

"We found that the manufacturers were actually testing the exhaust system and developing the exhaust system on the customer who bought the airplane. For example, our studies showed that it took about six design changes in the exhaust system to produce a reliable system. It was our objective to develop qualification tests for exhaust systems that could be used for certification. In the process of accomplishing that, we added the better materials that were recommended to be tested along with the qualification test development.

"Six aircraft were tested in flight for exhaust system operating information: metal temperature, gas temperature, engine vibration, and the vibration of the exhaust systems. With this information we set up a ground test facility, developing realistic conditions based on our inflight information."

It became obvious from these studies, Slusher revealed, that the wrong material was being used in the exhaust systems. The temperatures that the exhaust systems had to operate under, under the most severe conditions were higher than the material was recommended to withstand.

Two popular brand engines are turned up on stands with the operators in the small building between them. Air from each plane's heater is ducted into large tanks directly behind each engine. The tanks simulate airplane cabins.

Asked if he recommended that Incoloy 800 be used in the exhaust system, Slusher remarked: "We in the Government can't come out and say that; we'd prefer to say we recommend a product that is 20% chromium, 30% nickel or something, and refer to it in a manner where we don't mention a trade name. I would like to say that this product we found to be the best; and the properties we found in this product are the best for lightplane exhausts—not the trade name, just the inherent properties. The trade name is Incoloy Alloy 800, and in recent tests I've found it to be corrosion-resistant through 600 hours of testing."

Based on its findings to date, Slusher says the FAA should require manufacturers to run a qualification test on their exhaust systems if they use exhaust-type heaters. If the manufacturers change their design to incorporate what he calls fail-safe design principles, then they would not have to conduct a qualification test. The FAA recommends that manufacturers incorporate fail-safe designs.

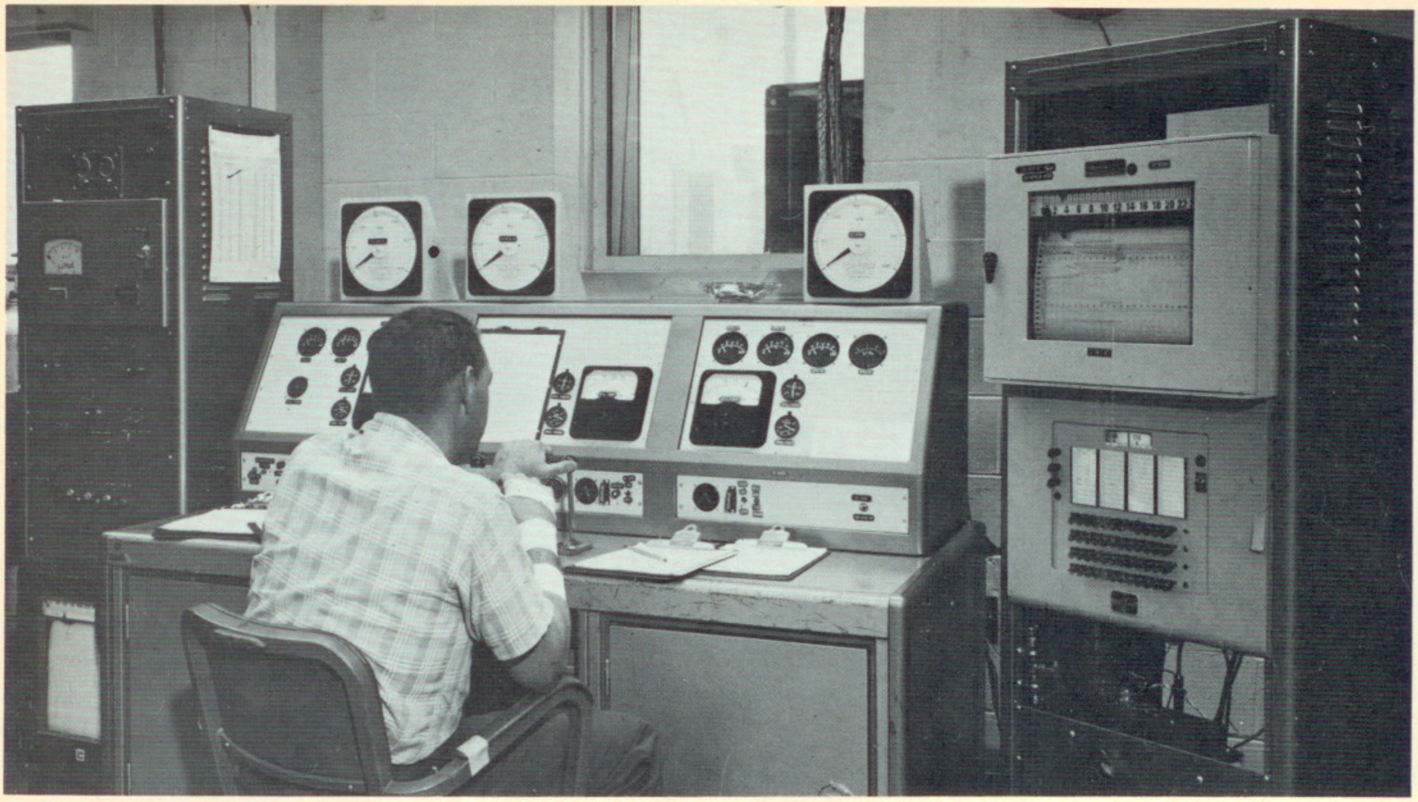
Asked what fail-safe designs the FAA recommends, Slusher said: "The first one, of course, is a double-wall type heat exchanger or muffler where the inner cavity might be vented overboard or pressurized with a gauge or light indicating pressure in the cabin; and if the inner wall fails, then the exhaust gases will either be thwarted overboard or an indication of pressure loss would exist in the cabin. The second way—actually, aerodynamically they could reduce the pressure of the exhaust through increasing the size of the muffler outlet, the tail-pipe outlet, and reduce the pressure of the exhaust where it wouldn't come out of cracks that could develop. There are other methods of producing fail-safe designs that may use something like a venturi effect, for instance, in that exhaust gases could be speeded up to such a high exhaust gas speed, to go through this venturi, that the static pressure is reduced. Should a crack occur in that area, the exhaust gases would not come through. Venturi is a specially designed tube that increases the velocity of the exhaust gas in this area, and as such the static pressure is reduced. The simplest method of producing a fail-safe heater would be to simply incorporate two rolls in the muffler."

Aren't plane manufacturers doing this?

"Well, what has happened—you would have to enlarge the heater and this would make it weigh more, or else reduce the efficiency of the heater. There should be certain considerations in lieu of running a qualification test."

How about the 30% nickel and 20% chromium?

"In a well-designed heater such as the one we have been mentioning, with this material which is more resistant to high temperatures, the products in question would certainly make the heater last much longer. But at the same time, if they don't change the design, etc., there is always the possibility of getting a failure with that. You see, the new material is only good from the standpoint of reducing the high temperature corrosion. It is not any advantage from the standpoint of fatigue. In other words, a fatigue crack in the area of stress concentration would still occur.



Engineer at control panel operates engine on test stand. Gauges are typical engine instruments: r.p.m., temperature and pressure. Console on far left takes carbon monoxide measurements from simulated airplane cabin, while console on right records exhaust gas temperatures.

It has been our estimate that about 40% of current failures could be reduced by incorporating the new materials or the most resistant material."

The FAA light aircraft exhaust project manager then commented on what his recommendations will do to the size of the exhaust system, its price, and its effect on the total weight of the aircraft. "The exhaust system itself runs from 10 to 17 pounds total right now—in that range. If you increase the weight of the double wall here, for instance, the muffler itself would be the only part of the exhaust system that would be increased. The muffler would go up 30% to 50% in weight, and that might add as much as 5 to 7 pounds to the weight of the plane. The price increase would involve the price of the materials. The current material would be about 50¢ a pound so that wouldn't be much—about $3—and with the new materials, it would probably run about $5 or $6."

Why, then, have manufacturers been so hesitant to make a change?

"Well, they are still operating on the theory that they want to make an economical heater and the most economical exhaust system and the lightest that they can. Any changes, of course, will have to be forced on them."

Seven pounds at $3.50 has to be forced on them?

"That's right. They don't have an engine nacelle with sufficient room. In other words, they will have to redesign their area there inside the nacelle to provide additional space to put this in there."

Slusher was asked what a private pilot can do to avoid and to guard against exhaust leakage in his own small plane.

"He should write to the manufacturer of the aircraft and advise him that he would like a safer exhaust system which could be incorporated with all fail-safe design principles and with new, more resistant materials in a thickness of .050."

What will the manufacturer do?

"The manufacturer will do something. These light aircraft owners will buy a different make next time if the situation isn't changed."

Then it is as simple as that: if something isn't done about it then they won't buy the product!

"Right! It is just like a car. If you have a lot of trouble with it, you don't buy another car of the same make."

Slusher then had some remarks about the other phase of his project. "We evaluated a low-cost carbon monoxide indicator—that is, indicators that sell for about $1 each. They are small plastic cards with a chemically treated spot in the center. On exposure to carbon monoxide, the spot turns darker than the color of the card. It serves as a warning in case of carbon monoxide contamination. We developed a color scale to go with the protector. By timing the exposure, you can determine if safe, marginal, or dangerous concentrations of carbon monoxide exist. As a matter of fact, it has been sold here in the United States. It has been imported from Denmark. The brand name is Detector. This is sold along with a color scale we developed, and the optimum situation is when one of these cards is kept exposed in the cabin for periods up to a month. We recommended using two Detectors, one sealed in its plastic case and the other exposed in the cabin. When it is noticed that the exposed Detector has darkened or changed color, then the pilot could take out his sealed Detector and time the exposure, compare it with the color scale, and see if a safe, marginal, or dangerous concentration of carbon monoxide is present. Of course, we have to look at the deficiencies and limitations of the Detector. It is only a temporary device, good up to a month of exposure under situations where there is no carbon monoxide." □

THE AUTHOR

Gary Shenfeld, 32-year-old aerospace science editor at Westinghouse Broadcasting Company's KYW-TV in Philadelphia, Pa., could be considered an expert on FAA's National Aviation Facilities Experimental Center at Atlantic City, N.J. While in his home town—which happens to be Atlantic City—Gary became interested in NAFEC and its aviation developments and wrote many feature articles about the FAA facility for the Atlantic City Press, the Philadelphia Bulletin, NBC News, and KYW-TV over a period of eight years. Following his graduation from the University of Miami, he went to work for WTVJ-TV at Miami, Fla. Shenfeld has received the Navy's Citizen Merit Achievement Award for television reporting. He is a member of the Aviation/Space Writers Association and Sigma Delta Chi (journalistic fraternity).