Silent Killer

If you think CO-related accidents are rare, think again…

On January 17, 1997, a Piper Dakota departed Farmingdale, New York, on a planned two-hour VFR flight to Saranac Lake, New York. The pilot was experienced and instrument-rated; his 71-year-old mother, a low-time private pilot, occupied the right seat. Just over a half-hour into the flight, Boston Center got an emergency radio call from the mother, saying that the pilot (her son) had passed out.

The controller attempted a flight assist, and an Air National Guard helicopter joined up with the aircraft and participated in the talk-down attempt. Ultimately, however, the pilot’s mother also passed out.

The aircraft climbed into the clouds, apparently on autopilot, and continued to be tracked by ATC. About two hours into the flight, the airplane descended rapidly out of the clouds and crashed into the woods near Lake Winnipesaukee, New Hampshire. Both occupants died.

Toxicological tests revealed that the pilot’s blood had a CO saturation of 43% — sufficient to produce convulsions and coma — and his mother's was 69%.

On December 6 that same year, a physician was piloting his Piper Comanche 400 from his hometown of Hoisington, Kansas, to Topeka when he fell asleep at the controls. The airplane continued on course under autopilot control for 250 miles until it ran a tank dry and (still on autopilot) glided miraculously to a soft wings-level crash-landing in a hay field near Cairo, Missouri.

The pilot was only slightly injured, and walked to a nearby farmhouse for help. Toxicology tests on a blood sample taken from the lucky doc hours later revealed CO saturation of 27%. It was almost certainly higher at the time of the crash.

Just a few days later, a new 1997 Cessna 182S was being ferried from the Cessna factory in Independence, Kansas, to a buyer in Germany when the ferry pilot felt ill and suspected carbon monoxide poisoning. She landed successfully and examination of the muffler revealed that it had been manufactured with defective welds. Subsequent pressure tests by Cessna of new Cessna 172 and 182 mufflers in inventory revealed that 20% of them had leaky welds. The FAA issued an emergency
Airworthiness Directive (AD 98-02-05) requiring muffler replacement on some 300 new Cessna 172s and 182s.

About 18 months later, the FAA issued AD 99-11-07 against brand new air-conditioned Mooney M20R Ovations when dangerous levels of CO were found in their cabins.

Not just in winter

A search of the NTSB accident database suggests that CO-related accidents and incidents occur far more frequently than most pilots believe. Counterintuitively, these aren’t confined to winter-time flying with the cabin heat on. Look at the months during which the following accidents and incidents occurred during the 15-year period from 1983 to 1997:

March 1983. The Piper PA-22-150 N1841P departed Oklahoma City, Okla., with enroute stops planned at Amarillo, Texas, and Tucumcari, N.M. At Tucumcari, the occupants found themselves “staggering a little” and concluded this was from exposure to high altitude. After leveling at 9,600 feet on the next leg of the flight, the right front seat passenger became nauseous, vomited, and fell asleep. The pilot began feeling sleepy and passed out. The aircraft began a circling descent, and efforts by the rear seat passengers to revive those in the front seats were unsuccessful. A 15-year-old passenger in the back seat took control of the aircraft by reaching between the seats, but the aircraft hit a fence during the emergency landing. None of the four occupants were injured. Multiple exhaust cracks and leaks were found in the muffler. The aircraft had recent annual and 100-hour inspections. The NTSB determined probable cause to be incapacitation of the pilot-in-command due to carbon monoxide poisoning.

March 1984. The pilot of Beech Musketeer N6141N with four aboard reported that he was unsure of his position. ATC identified the aircraft and issued radar vectors toward Ocean Isle, N.C. Subsequently, a female passenger radioed that the pilot was unconscious. ATC and another aircraft tried to assist, but the aircraft crashed in a steep nose-down attitude, killing all occupants. Toxicological tests of the four victims revealed carboxyhemoglobin levels of 24%, 22%, 35% and 44%.

November 1988. The Cessna 185 N20752 bounced several times while landing at Deadhorse, Alaska. The pilot collapsed shortly after getting out of the airplane. Blood samples taken from the pilot three hours after landing contained 22.1% carboxyhemoglobin. The left engine muffler overboard tube was broken loose from the muffler where the two are welded, allowing exhaust gas to enter the cockpit through the heater system. The overboard tube had a .022-inch-deep groove from rubbing against the engine cowling. The muffler had been installed during the last 100-hour inspection, 68 hours prior to the incident. The NTSB determined probable cause to be physical impairment of the pilot-in-command due to carbon monoxide poisoning.

July 1990. While on a local flight, the homebuilt Olsen Pursuit N23GG crashed about three-tenths of a mile short of Runway 4 at Fowler, Colo. No one witnessed the crash, but post-crash investigation indicated that there was no apparent forward movement of the aircraft after its initial impact. The aircraft burned, and both occupants died. Investigators found no evidence of mechanical failure, but toxicology tests of the pilot and passenger were positive for carboxyhemoglobin. The specific source of the carbon monoxide was not determined.

August 1990. About fifteen minutes into the local night flight in a Cessna 150 N741MF, the aircraft crashed into Lake Michigan about one mile from the shoreline near Holland, Mich. Two days later, the wreckage of the aircraft was found in 50 feet of water, with the passenger's body still strapped in. The pilot's body was found 12 days later when it washed onto the shore. Autopsies were negative for drowning, but toxicological tests were positive for carboxyhemoglobin, with the pilot's blood testing at 21%.

July 1991. The student pilot and a passenger (!) were on a pleasure flight in Champion 7AC N3006E owned by the pilot. The aircraft was seen to turn into a valley in an area of mountainous terrain, where it subsequently collided with the ground near Burns, Ore., killing both occupants. Although the aircraft was three years out of annual, investigators found no evidence of pre-impact mechanical failure. A toxicology exam of the pilot's blood
showed a saturation of 20% carboxyhemoglobin, sufficient to cause headache, confusion, dizziness and visual disturbance. [SEA91FA156]

October 1992. The pilot of a Cessna 150 N6402S was in radio contact with the control tower at Mt. Gilead, Ohio, and in a descent from 5,000 feet to 2,000 feet in preparation for landing. Seven miles south of the airport, the airplane was observed on radar flying away from the airport. Radar contact was lost, and the aircraft crashed into a wooded area, seriously injuring the pilot. Toxicological tests on the pilot’s blood were positive for carbon monoxide. Examination of the left muffler revealed three cracks and progressive deterioration. The NTSB found probable cause of the accident to be pilot incapacitation due to carbon monoxide poisoning. [NYC93LA031]

April 1994. Fifteen minutes after takeoff from Long Beach, Calif., the Cessna 182 N9124G began deviating from headings, altitudes and ATC instructions. ATC said the aircraft’s course became increasingly erratic as the flight continued, and that the pilot seemed disoriented. The aircraft drifted significantly off the assigned airway and headings, and did several 360- and 180-degree turns. The pilot reported blurred vision, headaches, nausea, labored breathing, and difficulty staying awake. The aircraft ultimately crashed in a vineyard near Kerman, Calif., following an uncontrolled altitude deviation, and the owner/pilot was seriously injured. Post-crash inspection revealed numerous small leaks in the exhaust system. The pilot tested positive for carbon monoxide even after 11 hours of oxygen therapy. [LAX94LA184]

October 1994. A student pilot returned to Chesterfield, Mo., from a solo cross-country flight in a Cessna 150 N7 XC, complaining of headache, nausea, and difficulty walking. The pilot was hospitalized, and medical tests revealed elevated CO which required five and a half hours breathing 100% oxygen to reduce to normal levels. Post-flight inspection revealed a crack in an improperly repaired muffler that had been installed 18 hours earlier. [CH195IA030]

March 1996. The pilot of a Piper Cherokee 140 N95394 stated that she and her passenger became incapacitated after takeoff from Pittsburg, Kan. The airplane impacted the

A QUICK PRIMER ON CO

What is carbon monoxide (CO)? It’s an invisible, odorless, colorless gas, so you have no way of detecting it without special instrumentation.

Where does it come from? CO is a byproduct of the incomplete combustion of fossil fuels such as gasoline. Complete combustion produces harmless carbon dioxide (CO2), whereas carbon monoxide (CO) is formed when there’s not enough oxygen present to completely oxidize the fuel - in other words, a rich mixture. The highest concentrations of CO in the exhaust tend to occur during the phases of flight when the mixture is richest - ground operations, takeoff, climb, instructional flights, etc. The more aggressively the engine is leaned, the less CO it produces.

How does it get into the cabin? The most common way for large amounts of CO to find its way into the cabin of a single-engine piston aircraft is through the cabin heat system. When cabin heat is being used, any cracks or holes in the muffler can allow CO-rich exhaust gas to contaminate the cabin. However, smaller concentrations of CO - enough to make you feel ill and impair your pilot skills - can enter the cabin in many other ways, even if your exhaust system is perfectly leak-free. Inadequate sealing of the firewall, tail cone, doors, windows and wheel wells are common paths of entry for CO. Air conditioning systems mounted in the tail cone of single-engine aircraft have proven to be especially vulnerable.

What happens when you breathe it? When CO is inhaled, it combines with your hemoglobin to form “carboxyhemoglobin” (COHb). The COHb bond is over 200 times stronger than oxygen’s bond with hemoglobin. Thus, the CO effectively puts your hemoglobin out of commission and deprives your body of the oxygen it needs to function. Sensitive parts of your body like your nervous system, brain, heart and lungs suffer the most from this lack of oxygen.

What are the symptoms? Symptoms of mild CO poisoning include headache, fatigue, dizziness, vision problems (particularly double vision), nausea and increased pulse and respiration. (Unfortunately, these symptoms are often attributed to flu, indigestion or the common cold.) At higher levels of COHb saturation, you may suffer difficulty breathing, loss of consciousness, collapse, convulsions, coma and even death.

How long does it last? The super-strong nature of the COHb bond explains why even very tiny concentrations of carbon monoxide can poison you slowly over a period of several hours, and why it may take a long, long time for your body to eliminate CO builds up from your bloodstream. COHb typically has a “half-life” of more than five hours. So if you crash-land in a hayfield with COHb saturation of 40% (enough to make you pass out), your COHb level can be expected to drop to about 20% (still enough to make you very sick) after about five hours, to 10% (still enough to make you woozy at altitude) after 10 hours, and so forth. Breathing 100% oxygen reduces the half-life to about 2.5 hours.
terrain, but the occupants were uninjured. Both were hospitalized for observation, and toxicological tests for carbon monoxide were positive. A subsequent examination found holes in the muffler. An annual inspection had been completed four flight hours prior to the accident. [CHI96LA101]

**August 1996.** A Mankovich Revenge racer N7037J was #2 in a four-airplane ferry formation of Formula V Class racing airplanes. The #3 pilot said that the #2 pilot's flying was erratic during the flight. The witness said when they were within a mile of the landing airport, the pilot "pulled straight up, pulled left to the east at full power, then went into a slight descent." The witness said that he flew up alongside the pilot's airplane to try to get his attention. "I couldn't get his eye. He would not even look at me. I chased him about five miles before I lost sight of him. The last time I saw him, he was below 500 feet." The airplane crashed near Jeffersonville, Ind., killing the pilot. The results of FAA toxicology tests of the pilot's blood revealed a 41% saturation of carboxyhemoglobin; loss of consciousness is attained at approximately 30%. Examination of the wreckage revealed that the adhesive resin that bound the rubber stripping forming the firewall lower seal was missing. The NTSB determined probable cause of the accident to be pilot incapacitation due to carbon monoxide poisoning. [CHI96FA322]

**January 1997.** The fatal crash of a Piper Dakota N8263Y near Lake Winnipesaukee, N.H. (described previously). [IAD97FA043]

**December 1997.** Non-fatal crash of a Piper Comanche 400 N8452P flying from Hoisington to Topeka, Kansas (described previously). [CHI98LA055]

**December 1997.** A new Cessna 182S was being ferried from the factory in Independence, Kan., to a buyer in Germany when the ferry pilot felt ill and suspected carbon monoxide poisoning (described previously). [Priority Letter AD 98-02-05]

Overall, deaths from unintentional carbon monoxide poisoning have dropped sharply since the mid-1970s thanks mainly to lower CO emissions from automobiles with catalytic converters (most CO deaths are motor vehicle-related) and safer heating and cooking appliances. But CO-related airplane accidents and incidents haven’t followed this trend. The ADs issued against Independence-built Cessna 172s and 182s and Mooney Ovations demonstrates that even brand new airplanes aren’t immune.

**Close calls**

In addition to these events in the NTSB accident database where CO poisoning was clearly implicated, there were almost certainly scores of accidents, incidents, and close calls where CO was probably a factor.

**In January 1999,** for example, a Cessna 206 operated by the U.S. Customs Service was on a night training mission when it inexplicably crashed into Biscayne Bay a few miles off the south Florida coast. The experienced pilot survived the crash, but had no recollection of what happened. The NTSB called it simple pilot error and never mentioned CO as a possible contributing factor. However, enough carboxyhemoglobin was found in the pilot’s blood that the Customs Service suspected that CO poisoning might have been involved.

The agency purchased sensitive industrial electronic CO detectors for every single-engine Cessna in its fleet, and discovered that many of the planes had CO-in-the-cockpit problems. On-board CO detectors and CO checks during maintenance inspections have been standard operating procedure for the Customs Service ever since.

**How much CO is too much?**

Apparently, it depends on whom you ask.

EPA calls for a health hazard alert when the outdoor concentration of CO rises above 9 parts per million (ppm) for eight hours, or above 35ppm for one hour. OSHA originally established a maximum safe limit for exposure to CO in the workplace of 35 ppm, but later raised it to 50 ppm under pressure from industry.

The FAA requires that CO in the cabin not exceed 50 ppm during certification testing of new GA airplanes certified under FAR Part 23 (e.g. Cessna Corvallis, Cirrus SR22, Diamond DA-40). Older designs certified under older CAR 3 regs (including most Cessna aircraft) required no CO testing at all
during certification.

Once certified, FAA requires no CO testing of individual aircraft by the factory, and no follow-up retesting during annual inspections. A March 2010 FAA SAIB (CE-10-19 R1) recommends checking CO levels with a hand-held electronic CO detector during ground runups at each annual and 100-hour inspection, but in my experience very few shops and mechanics do this.

UL-approved residential CO detectors are not permitted to alarm until the concentration rises to 70 ppm and stays there for four hours. (This was demanded by firefighters and utility companies to reduce the incidence of nuisance calls from homeowners.) Yet most fire departments require that firefighters put on their oxygen masks immediately when CO levels reach 25 ppm or higher. Some doctors believe that long-term exposure to CO levels as low as 10 ppm can lead to cognitive and physical problems.

Whomever you believe, it’s important to understand that low concentrations of CO are far more hazardous to pilots than to non-pilots. That’s because the effects of altitude hypoxia and CO poisoning are cumulative. For example, a COHb saturation of 10% (which is about what you’d get from chain-smoking cigarettes) would probably not be noticeable to someone on the ground. But at 10,000 feet, it could seriously degrade your night vision, judgment, and possibly cause a splitting headache.

After studying this hazard for many years and consulting with world-class aeromedical experts, I have come to the following conclusions:

1. Every single-engine piston aircraft should carry a sensitive electronic CO detector.

2. Any in-flight CO concentration above 10 ppm should be brought to the attention of an A&P for troubleshooting and resolution.

3. Any in-flight CO concentration above 35 ppm should be grounds for going on supplemental oxygen (if available) and making a precautionary landing as soon as practicable.

Speaking of cigarettes: If you must smoke, for heaven’s sake don’t do it before you fly! Smokers are far more vulnerable to both altitude hypoxia and CO poisoning, since they’re already in a partially poisoned state when they first get into the aircraft. Because of COHb’s long half-life, you’d do well to abstain from smoking for 8 to 12 hours prior to flight.

**Choosing a CO detector**

*Five CO detectors (left to right): chemical spot, UL-compliant residential (Kidde), non-UL-compliant (CO Experts 2015), industrial (BW Honeywell), TSO’d panel-mounted (CO Guardian 551).*
**Chemical spot detectors:** Stay away from those ubiquitous el-cheapo adhesive-backed cardboard chemical spot detectors that are commonly sold by pilot shops and mail-order outfits for $3.50 to $6 under trade names like “Dead Stop,” “Heads Up” and “Quantum Eye.” They have a very short useful life (about 30 days), and are extremely vulnerable to contamination from all sorts of aromatic cleaners, solvents and other chemicals that are routinely used in aircraft maintenance.

These things often remain stuck on the instrument panel for years, providing a dangerous false sense of security: What's worse, there's no warning that the detector is outdated or has been contaminated—in some ways, that's worse than not having a detector at all.

Even when fresh, chemical spot detectors are incapable of detecting low levels of CO. They'll start turning color at 100ppm, but so slowly and subtly that you'll never notice it. For all practical purposes, you'll get no warning until concentrations rise to the 200 to 400 ppm range, by which time you're likely to be too impaired to notice the color change.

**Residential electronic detectors:** Although battery-powered residential electronic detectors are vastly superior to those worthless chemical spots, most are designed to be compliant with Underwriter’s Laboratory specification UL-2034 (revised 1998). This spec requires that:

1. The digital readout must not display any CO concentration less than 30 ppm.
2. The alarm will not sound until CO reaches 70 ppm and remains at or above that level for four hours.
3. Even at a concentration of 400 ppm, it may take as much as 15 minutes before the alarm sounds. This makes them of marginal value in the cockpit.

For aircraft use, you really want something much more sensitive and fast-acting. I like the non-UL-compliant CO Experts Model 2015 ($199 from www.aeromedix.com). It displays CO concentrations as low as 10 ppm and provides a loud audible alarm at concentrations above 25 ppm. It updates its display every 10 seconds (compared to once a minute for most residential detectors), which makes it quite useful as a “sniffer” for trying to figure out exactly where CO is entering the cabin.

**Industrial electronic detectors:** Industrial CO detectors cost between $400 and $1,000. A good choice for in-cockpit use is the BW Honeywell GasAlert Extreme CO ($410 from www.gassniffer.com). This unit displays CO concentrations from 0 to 1,000 ppm on its digital display, has a very loud audible alarm with dual trigger levels (35 and 200 ppm).

**Purpose-built aviation electronic detectors:** Tucson-based CO Guardian LLC makes a family of TSO’d panel-mount electronic CO detectors specifically designed for cockpit use. These detectors detect and alarm at 50 ppm (after 10 minutes), or 70 ppm (after 5 minutes), and will alarm instantly if concentrations rise to 400 ppm. The digital display models ($599 and up) will show concentrations as low as 10 ppm. Available from www.coguardian.com. Obviously, panel-mount detectors cannot be used as a sniffer to locate the source of a CO leak.

**CO EMERGENCY CHECKLIST**

If your electronic CO alarm goes off in flight, what should you do? Here are some suggestions:

1. Start breathing supplemental oxygen (if available). Turn up the oxygen flow to maximum. Going on O2 will reduce your CO intake and will increase the rate at which your COHb saturation will dissipate.
2. Lean the engine as aggressively as possible to reduce the CO content of the exhaust. An engine operating lean of peak (LOP) has very low levels of CO in its exhaust.
3. If the cabin heat is on, shut it off. Cabin heat is the principal cause of high-level CO contamination in single-engine airplanes.
4. Open all cabin fresh-air vents. In most cases, this will help reduce CO in the cabin. Under rare conditions, however, it could have the opposite effect - so keep a close eye on the CO concentration readout. (A fast-acting readout is a big help here.) DO NOT open the pilot storm window, because doing so reduces cabin pressure and will usually make things worse.
5. Take steps to land the airplane as soon as practicable. If CO concentration is above 50-70 ppm, or if you have any symptoms of CO poisoning or hypoxia (e.g., headache, nausea, double vision), consider declaring an emergency.
For more information…

There is an outstanding October 2009 research paper titled “Detection and Prevention of Carbon Monoxide Exposure in General Aviation Aircraft” authored by Wichita State University under sponsorship of the FAA Office of Research and Technology Development. The paper is 111 pages long, and discusses (among other things):

- Characteristics of CO-related GA accidents
- Evaluation of CO detectors, including specific makes and models
- Placement of CO detectors in the cabin
- Exhaust system maintenance and inspection

This research paper is available online at:

See you next month.

Tech Topics is a monthly column written by Mike Busch of CPA’s technical staff. Mike is a longtime CPA Magazine columnist, and is founder and CEO of Savvy Aircraft Maintenance Management, Inc. (www.savvymx.com) that provides professional maintenance management for Cessnas and other owner-flown GA aircraft. Mike is the National AMT of the year for 2008. Mike owns, flies and maintains a 1979 Cessna T310R based in Santa Maria, California.

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