DARING TO INHALE

Research clarifies factors that mitigate risks to aircraft occupants when using hand-held fire extinguishers.

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Aircraft crewmembers in the United States were reminded in 2004 they should initiate aggressive firefighting without delay because halon extinguishing agents at recommended use concentrations are "relatively nontoxic" compared with exposure to combustion products of fires, and a new study by the Federal Aviation Administration (FAA) reiterates that advice.[1] Concerns of pilots and flight attendants about the toxicity[2] of halon vapors when discharging hand-held fire extinguishers inside aircraft were addressed at that time by the FAA in Advisory Circular (AC) 120-80, *In-Flight Fires,* and by a subsequent companion video and related educational material. The study's findings, however, have led to more conservative guidance about safe-use concentrations of Halon 1211, the predominant clean streaming agent in FAA-required hand-held extinguishers, the FAA said.

Several other halocarbon agents also were examined: Halon 1301, the clean flooding agent used primarily in other aircraft applications; a blend of these two halons; and three halon-equivalent agents — hydrochlorofluorocarbon (HCFC) blend B (Halotron I), and the hydrofluorocarbons (HFCs) 227ea and 236fa. The study included animal testing and mathematical modeling of the human health effects of inhaling the agents at their maximum recommended concentration levels, which depend on aircraft-compartment volume,[3] rates of air exchange in compartments, cabin pressure altitude and aircraft maximum certificated altitude, the study's final report said.

The FAA's updated guidance was introduced first in draft AC 20-42D, *Hand Fire Extinguishers for Use in Aircraft.* This draft AC, issued Oct. 13 for public comment until Nov. 27, is scheduled to replace the 25-year-old AC 20-42C of the same title.

Draft AC 20-42D covers other aspects of safe use of extinguishing agents, including fire-fighting effectiveness and selection, and the location and mounting of extinguishers. It also establishes these equivalent agents as approved replacements for Halon 1211 in the context of international environmental initiatives to phase out all uses of halons (*ASW,* 9/09, p. 29) and discourages the use of any other extinguishing agents in aircraft.

The guidance prevents high concentrations of the tested halocarbons that, if inhaled for less than five minutes, could induce cardiac arrhythmia — that is, abnormal electrical activity in the heart — and if inhaled longer than five minutes, could induce anesthetic effects, the report said. "This report recommends limits on the amount of [these agents] that can be used to fight fires in ventilated and unventilated aircraft compartments without adverse health effects due to inhalation of the agents themselves or low-oxygen concentration caused by agent displacement," the report said. "The technical basis for the prescribed safe-use limits of halocarbon extinguishing agents in aircraft is a simplified kinetic model that describes the halocarbon concentration history in the blood of humans exposed to gaseous halocarbon environments."

"Halon 1211 [guidance] is based on the *no observed adverse effect level* and *lowest observable adverse effect level* concentrations, as maximum safe human concentrations cannot be determined using equivalent methodologies to the other agents," the report said. "Maximum safe human concentrations are generally between [these] concentrations. … The minimum safe volume[4] must be calculated for the agent weight in a particular extinguisher."

Agent-specific discharge amounts for ranges of compartment volumes and operating conditions have been listed in the report's graphs and tables as a safe agent weight to compartment volume (W/V) ratio in pounds per cubic feet. The researchers determined that each known risk of agent inhalation can be mitigated by the updated guidance.

"The minimum safe volume is obtained by dividing the total agent weight by the maximum safe-use agent W/V for the appropriate altitude and aircraft ventilation," the report said. "The minimum safe volume for all extinguishers in a compartment is based on the weight of the agent in all of the bottles in an aircraft compartment."

The typical Underwriters Laboratories–rated 5B:C aircraft fire extinguisher — the capacity and type suitable for hand-held use on flammable liquids and gases and energized electrical equipment — meets FAA standards by combinations of agent weight, nozzle design, pressurization and other factors. The report's graphs and tables show the maximum safe W/V ratios for pressurized aircraft and for unpressurized aircraft, including ventilated and unventilated types equipped to operate up to altitudes of 12,500, 14,000, 18,000 and 25,000 ft. Halocarbon agents are heavier than air, and in pressurized airplanes, can be removed by selecting the air recirculation "OFF" so that the agent passes through floor-level exhaust grilles.

An unpressurized aircraft requires immediate action to mitigate adverse effects based on the study's analysis of minimizing occupant exposure to low-oxygen, partial-pressure environments that can occur when halocarbon agents are discharged in small, unpressurized compartments.

"With exposure times beyond five to 10 minutes at the minimum forecast alveolar [lung] oxygen pressure, some occupants could be incapacitated," the report said. "Thus, guidance on minimizing exposure by using aircraft ventilation and rapid descent is important not only for minimizing exposure to the halocarbon agents but also for minimizing hypoxic hazards in small compartments. … Immediate descent at the maximum safe rate to the lowest practicable altitude or 8,000 ft is recommended for all unpressurized aircraft to minimize exposure to halocarbon gases and reduce hypoxia resulting from the agent displacing oxygen from the air in the compartment. Occupants in unpressurized aircraft equipped to fly above 12,500 ft should immediately don oxygen masks or nasal cannula to prevent hypoxia."

Notes

1. Speitel, Louise C.; Lyon, Richard E. *Guidelines for Safe Use of Gaseous Halocarbon Extinguishing Agents in Aircraft.* FAA Office of Research and Technology Development. Final Report no. DOT/FAA/AR-08/3. August 2009.
2. *Toxicity* in the latest FAA research means an arterial blood concentration at which cardiac sensitization — the onset of electrical abnormalities in the heart when adrenalin is present — began based on canine exposure data, using beagle dogs, which could be applied to humans without data adjustments.
3. *Aircraft compartment* means an enclosed space such as a flight deck, cabin or crew rest facility.
4. *Minimum safe volume* means the smallest volume of space into which a hand-held fire extinguisher can be discharged without posing a toxicity hazard.