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When Circuit Breakers Trip, A Hands-off Policy Prevents Fires

More airlines prohibit flight attendants from manipulating circuit breakers — except with the captain's prior approval or when authorized explicitly by a written procedure.

FSF Editorial Staff

The importance of immediate, aggressive action by pilots and flight attendants confronted by signs of an in-flight fire has received significant attention. Ideally, their training also will include up-to-date reminders of risks involved in resetting circuit breakers (CBs) as discussed by the Transportation Safety Board of Canada (TSB) in the March 2003 report of its investigation of the 1998 Swissair Flight 111 accident.[1]

Unlike switches, CBs are safety devices designed to interrupt the flow of electrical current to prevent the overheating of wiring and connectors when current overloads or short circuits occur. The equipment connected to a CB typically has a separate internal circuit-protection system.

"The CB is known in the aviation community to be a simple, long-lasting and reliable component that is designed to provide protection for the aircraft's wires and cables throughout the life of the aircraft," said TSB. "As modern aircraft use more software-based equipment … CBs are being used more frequently as switches, as they are viewed as a convenient method of 'rebooting' the system when the software gets 'hung up.' … The routine use of a CB as a switch also has the potential to influence an individual's perception about the actual use and function of a CB."

In some situations, resetting a tripped (open) CB can overheat wiring, leading to wiring failures and to electrical arcing (also called arc faults), said a January 2004 advisory circular issued by the U.S. Federal Aviation Administration (FAA).[2] Resembling tiny lightning bolts, electrical arcs can ignite nearby flammable materials. Overheated wiring also might occur if a CB fails to trip because of a malfunction.

A thermal CB — the type used in aircraft cabins for about 50 years — trips when a predetermined overload of electrical current, sensed as a temperature increase caused by load-current heating, occurs within a specified time. The heating bends the CB's internal bimetallic strip (element), which mechanically opens the circuit.[3] These CBs are the manual-reset type, which means that pushing in the reset pushbutton will close the circuit when the CB has cooled sufficiently. As a rule, they also are designed to prevent manual override of the trip mechanism.[4]

Since the late 1990s, many airlines have adopted policies to better control how cabin crews interact with CBs. For example, at KLM–Royal Dutch Airlines, a revised policy for cabin-system CBs was implemented in March 2000. The policy was developed based on comparison of the aircraft flight manuals for company fleets and analysis of regulatory requirements and international safety recommendations.[5]

"In the past, to troubleshoot and restore/reactivate malfunctioning cabin systems — such as lavatories that became inoperative in flight — our cabin crews would use *Cabin Quick Reference Handbooks,* which provided procedures for manipulating CBs," said Jochem Weeink, senior engineer, safety equipment and procedures, for KLM.[6] "At all times, our purser would get in contact with the flight deck crew to discuss the problem, but [cabin-system] resetting by cycling CBs became much too routine and could result in the evolution of inappropriate CB-reset practices. [Cycling means pulling out and pushing in the reset pushbutton of a push-pull-type CB.] It was apparent that possible misuse of CBs would impair their function as a safety device. As a result, *Cabin Quick Reference Handbooks* then officially were withdrawn.

"To my knowledge, no consensus recommendation on resetting of CBs by cabin crewmembers exists in Europe or elsewhere. Inconsistent philosophies from aircraft manufacturers and authorities made it difficult to describe a common denominator, so we had to apply the most stringent [guidance] we could find. This resulted in a simple phrase in the [revised] *Cabin Safety Procedures Manual:* 'CBs are designed to protect the electrical systems against short circuit. CBs may only be reset or manipulated in concert with the cockpit crew.' As a result, any attempt to restore cabin systems always shall be initiated and coordinated from the flight deck. In most cases, their initial answer will be: 'Please don't touch a thing.'"

KLM also developed some galley-fire procedures for quickly opening electrical circuits without pulling CBs.

"Our CB policy covers a tripped CB — for example, due to a short circuit — cycling of a CB to resolve system malfunctioning and pulling a CB to switch off power in any cabin system," he said. "In case of an electrical problem in the galley, any cabin crewmember is authorized to switch off the galley main power switch located in each galley. This switch will cut off all electrical power to the entire galley complex, which we believe is necessary for fire fighting procedures. There is no need to touch any CB, and no authorization from the flight deck is needed.

"Every year, our cabin crews are reminded about the 'hands off' policy during recurrent fire fighting training, which is mandatory every three years under European Joint Aviation Requirements–Operations (JAR–OPS 1). Our CB policy is stressed again in a training environment with live fires in ovens, waste trolleys, seats and a lavatory, and using a 1.0-square-meter [10.8-square-foot] open fire with flames up to 2.0 meters [6.7 feet] high."

Factors influencing the worldwide shift in thinking about CBs included the following:

- Accident investigations that have raised awareness that flight attendant training plays a role in preventing in-flight fires, especially those caused by wiring faults. Based on FAA Order 8400.10, *Air Carrier Inspector's Handbook*, Volume 3, "Air Operator Technical Administration," FAA inspectors have advised U.S. airlines to provide flight attendant general emergency training for responding to smoke and fire "with emphasis on electrical equipment and related [CBs] found in cabin areas, including all galleys, service centers, lifts, lavatories and movie screens." Canadian flight attendant training standards provide an example of a specific requirement: "Identify the function of [CBs] in electrical panels and describe the procedures for tripped [CBs], including reset and crew communication procedures. Describe the potential hazards to flight safety if [CB] procedures are not followed";[7]

- In 2000, FAA summarized its philosophy, policy and regulations about resetting tripped CBs for air carriers in scheduled operation with airplanes having a passenger-seat configuration of 10 or more seats or a payload capacity of more than 7,500 pounds/3,400 kilograms, and said, "The overriding message is one of caution. … There is a latent danger in resetting a CB tripped by an unknown cause because the tripped condition is a signal that something may be wrong in the related circuit. … Resetting a CB tripped by an unknown cause should normally be a maintenance function conducted on the ground"; and,[8]

- Although thermal CBs provide a basic level of protection, FAA considers them "slow-acting devices [that] may not offer sufficient disconnect protection during events such as arc tracking or insulation flashover." (Arc tracking occurs when a conductive carbon path is formed across an insulating surface so that current flowing along this short-circuit path produces electrical arcing. Insulation flashover, a result of arc tracking, is an instantaneous burn-through of the insulated wire with the possibility of continuing the burn into surrounding wires.)

Airlines should develop training programs, manuals and general safety awareness, emphasizing strict adherence to CB-reset procedures derived from the recommendations of aircraft manufacturers, FAA said.

"Crewmembers may create a potentially hazardous situation if they reset a CB without knowing what caused it to trip," FAA said. "A tripped CB should not be reset in flight unless doing so is consistent with explicit procedures specified in the approved operating manual or unless, in the judgment of the captain, resetting the CB is necessary for the safe completion of the flight."[9]

One result has been more airline policies under which flight attendants only reset CBs at the captain's direction and do not reset any CB more than once.[10] The captain takes responsibility for judging whether resetting the CB is necessary for the safe completion of the flight.

Nevertheless, years of resetting CBs can affect any aircraft crewmember's habits and expectations.[11] Non-safety-related motivations still can come into play, such as desire to continue working with a galley oven to complete a meal service, to restore serviceability of a lavatory component or to restart the software of an in-flight entertainment system.[12]

"What was acceptable before for all the crewmember work groups is not acceptable anymore," said Candace Kolander, coordinator, air safety, health and security, for the Association of Flight Attendants, a U.S. union. "Hopefully, there will be greater focus on CBs in training since publication of the FAA advisory circular on in-flight fires."

Among the most likely times when a flight attendant might be motivated to reset a cabin CB is while preparing for the first flight of the day, Kolander said. If a galley oven cannot be powered and its associated CB is inexplicably pulled out, two assumptions might be made: that the CB unintentionally was left open by a maintenance crew and that pushing in the CB-reset pushbutton once carries no risks. A CB-reset policy and procedure should cover this scenario — for example, by reporting to the captain any open CB identified during preflight checks.

"Otherwise, if the oven was working but then stopped working because a CB tripped, the flight attendant's mental red flags should go up," she said.

The FAA advisory circular on in-flight fires explains the specific fire hazards associated with resetting CBs.

"A majority of hidden in-flight fires [i.e., fires behind cabin sidewall paneling or in overhead areas] are the result of electrical arcs along wire bundles," FAA said. "In most cases, the electrical arc acts as the initiating event, igniting other surrounding materials. The surface of insulation materials is often a conveyor of these initiating events, as contamination from spillage, accumulated dirt/dust, lubrication or corrosion inhibitors on these surfaces can promote flame spread (uncontaminated insulation materials are generally very fire resistant). In other instances, the resetting of a tripped [CB] can overheat wiring, ultimately leading to failure and arcing, causing the same chain of events. … A malfunctioning CB that does not open (trip) when an abnormally high current draw is detected may cause the affected unit or associated wiring to overheat and ignite. … [CBs] tripping, especially multiple [circuit] breakers such as entertainment systems, coffee makers, etc. may be an indication of damage occurring in a hidden area common to the affected components. … Failure or uncommanded operation of an aircraft component may indicate a developing fire. Electrical connections and the components themselves may have been damaged by a fire in the area of the component or at any point along its power-supply line. For this reason, cabin crewmembers should report all failures of electrical items to the flight [deck] crew in accordance with company policy."[13]

Electrical arcs may cause problems such as overheating of cabin equipment; smoke; toxic fumes; fire; melting/burning damage to wires, wire bundles and parts; and electromagnetic interference with critical aircraft electronic equipment. The FAA advisory circular also said, "[CBs], even those suitable for frequent operation, should not be used as a switch to turn protected items on or off. Exceptions to this procedure should be published and included in an air carrier's approved maintenance program and flight operations manuals."

Newly developed "smart" circuit-protection devices for aircraft soon are expected to reduce the risk that electrical arcs will go undetected. Called arc fault circuit breakers (AFCBs), they supplement the conventional thermal-CB mechanism with a built-in electronic device.

"Significant progress is being made toward the development of AFCBs," said Thomas E. Potter, arc fault business manager for Texas Instruments and former chairman of the SAE International subcommittee that is defining a performance specification for AFCBs that may be installed on aircraft.[14] Some specialists expect that, when approved, the first generation of AFCBs will be used initially in non-flight-critical circuits such as those protected by cabin CBs (especially in retrofit applications such as galley ovens and in-flight entertainment systems), he said. Externally, an AFCB looks like a current thermal CB.

"A major aircraft OEM [original equipment manufacturer] has initiated qualification efforts on production AFCBs, an industry standard specification[15] is being finalized for ballot [approval/disapproval by vote] in the second quarter of 2004, and flight trials on transport category aircraft are ongoing without any in-flight anomalies," Potter said.

AFCBs have been designed to function without nuisance (inappropriate) trips on various types of aircraft loads, and the line-operations experience gained from ongoing in-flight trials will help engineers to mitigate such trips, he said. When approved, the specification will enable civil aviation authorities and aircraft manufacturers to utilize (or require installation) of AFCBs for enhanced circuit protection.

"Installation and retrofit of AFCBs in the cabin will not require any change to circuit-breaker-related safety procedures for flight attendants — or for flight crews in the cockpit," Potter said.

Unlike most safety-related duties of cabin crews, remembering what *not* to do with a CB may be counterintuitive unless the airline provides and reinforces a specific policy on cabin CBs.♦

Notes

1. Transportation Safety Board of Canada (TSB). *Aviation Investigation Report no. A98H0003, In-flight Fire Leading to Collision with Water, Swissair Transport Limited, McDonnell Douglas MD-11, HB-IWF, Peggy's Cove, Nova Scotia 5 nm SW, 2 September 1998*. March 27, 2003. At 2018 local time on Sept. 2, 1998, Swissair Flight 111 struck the ocean about 5.0 nautical miles (9.3 kilometers) southwest of Peggy's Cove, Nova Scotia, Canada, while the crew was diverting to Halifax International Airport, Nova Scotia, after an abnormal odor, smoke and fire progressively were detected in the cockpit. The 215 passengers and 14 crewmembers were killed; the aircraft was destroyed. TSB, in its final report, said that causes and contributing factors included inadequate aircraft certification standards for material flammability; flammable cover material on acoustic insulation blankets; flame-propagation characteristics of thermal acoustic insulation cover materials; silicone elastomeric end caps, hook-and-loop fasteners, foams, adhesives and thermal acoustic insulation splicing tapes that contributed to the propagation and intensity of the in-flight fire; and circuit breakers, similar to those in general aircraft use, that were not capable of protecting against all types of wire arcing events. "The fire most likely started from a wire arcing event," TSB said.

2. U.S. Federal Aviation Administration (FAA). Advisory Circular 120-80, *In-flight Fires*. Jan. 8, 2004.

3. Murphy, Mike. "The Deliberately Weak Link in the Electrical Chain." *Aviation Safety Letter*. Transport Canada. January 2001.

4. U.S. Navy. *Navy Electricity and Electronics Training Series, Module 20—Master Glossary*. NAVEDTRA 14192. September 1998. A trip-free circuit breaker (CB) will open the circuit during an overcurrent condition and cannot be held in the ON (closed) position by pushing in and holding the reset pushbutton. With a non-trip-free CB, the reset pushbutton can be pushed in and held in the ON position during an overcurrent condition.

5. Weeink, Jochem. Telephone and e-mail communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S. March 12, 2004, and March 16, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S.

6. Weeink.

7. Transport Canada, Safety and Security. *Flight Attendant Training Standard TP 12296 E, Annual – Part Six – Aircraft Specific*. April 1, 1996.

8. FAA. Joint Flight Standards Information Bulletin for Air Transportation (FSAT) 00–07A, *Resetting Tripped Circuit Breakers*. Aug. 21, 2000.

9. FAA. AC 120–80.

10. Claussen, Nancy. E-mail communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S. March 8, 2004. Claussen, an FAA aviation safety inspector (cabin safety), said that during 2004, information from FSAT 00–07A will be incorporated into a new chapter titled "Cabin Safety and Flight Attendant Management" in FAA Order 8400.10, *Air Carrier Inspector's Handbook* — underscoring the importance of a CB policy for cabin crews.

11. TSB.

12. Gallagher, Sheryl; Grant, Howard. E-mail communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S. March 11, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S. Gallagher and Grant, both cabin safety inspectors for the Australian Civil Aviation Safety Authority, trained cabin crews earlier in their careers. "We always taught that cabin crew should report any CBs that [tripped] to the captain and, on his advice, turn all power off, reset the circuit in the galley and then return to normal power," Gallagher said. "In the event the CB [tripped] again, it was reported but not reset, and was written up by the captain in the maintenance log." Grant said, "I recall an occurrence close to home (in my previous life) where an oven CB was [tripping] from Melbourne [Victoria, Australia] to Auckland [New Zealand]. The 'senior' [lead flight attendant] at the back [pushed in the CB-reset pushbutton] because the meals were nearly ready. It [tripped] a master [CB] on the flight deck, and the aircraft was on the ground for several days while the galley was rewired."

13. FAA. AC 120–80.

14. Potter, Thomas E. E-mail communication with Rosenkrans, Wayne. Alexandria, Virginia, U.S. March 12, 2004. Flight Safety Foundation, Alexandria, Virginia, U.S. Potter currently leads Task Group 1, the working group of the SAE International AE–8B1 Protective Devices subcommittee that is developing the first arc fault circuit breaker (AFCB) performance specification and two additional AFCB specifications.

15. SAE International's draft performance specification is called SAE Aerospace Standard 5692, "Arc Fault Circuit Breaker (AFCB), Aircraft, Trip-Free Single Phase 115 VAC, 400 Hz – Constant Frequency."