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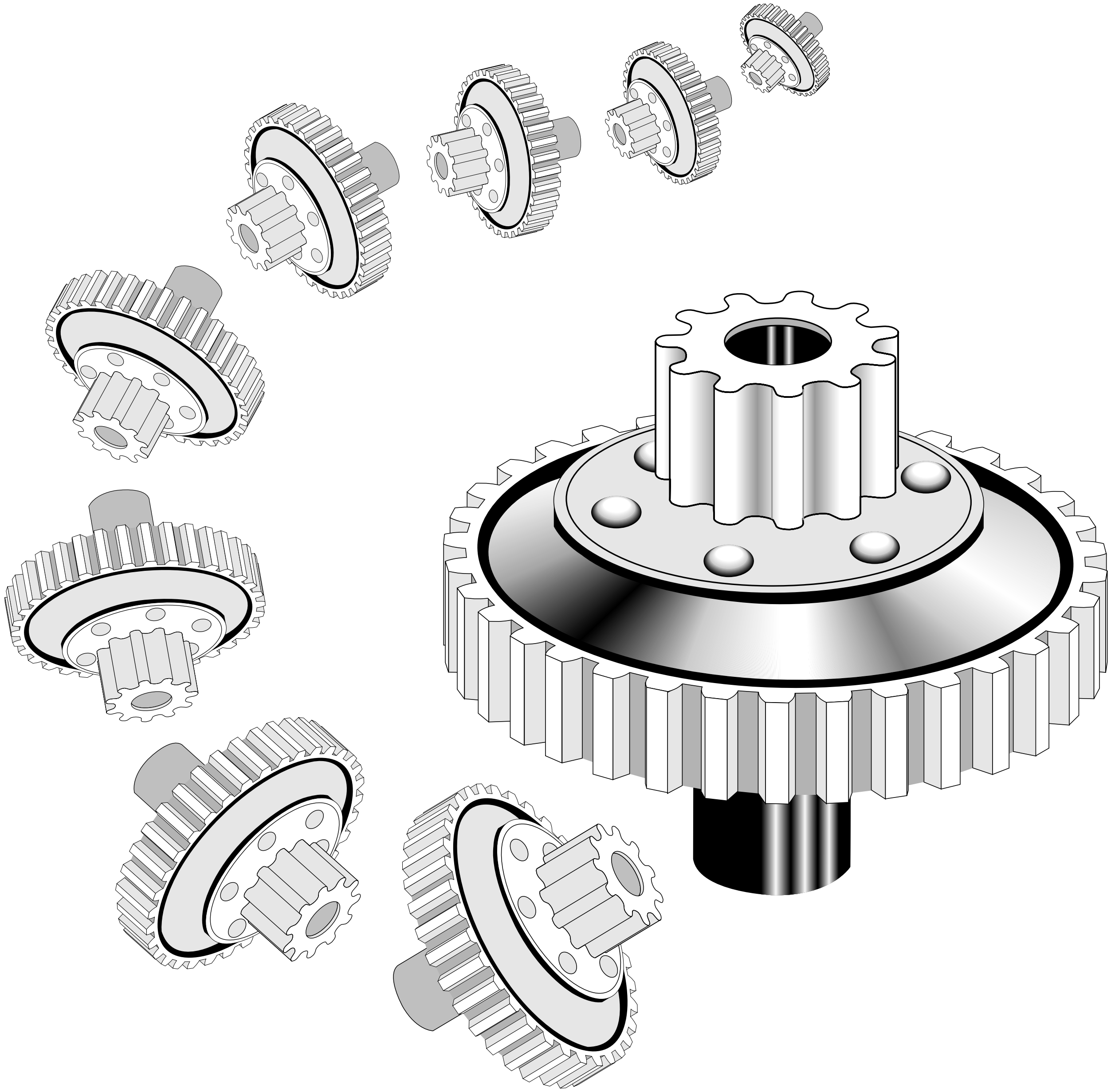
SPECIAL DOUBLE ISSUE

Bogus Parts — Detecting the Hidden Threat



Flight Safety Digest

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Flight Safety Foundation is an international membership organization dedicated to improving aviation safety. Nonprofit and independent, the Foundation was launched in 1945 in response to the aviation industry's need for a neutral clearinghouse to disseminate objective safety information, and for a credible and knowledgeable body that would identify threats to safety, analyze the problems and recommend practical solutions to them. Since its beginning, the Foundation has acted in the public interest to produce a positive influence on aviation safety. Today, the Foundation provides leadership to nearly 600 member organizations in 75 countries.

Bogus Parts — Detecting the Hidden Threat

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Editorial Staff Report

On Sept. 8, 1989, a chartered twin-engine Convair 340/580 turboprop aircraft with 50 members of a Norwegian shipbuilding company and a crew of five on board disappeared from radar as it approached the northern coast of Denmark. Minutes later, search and rescue teams discovered wreckage floating about 10 miles offshore. There were no survivors. (See "Fatal Convair Crash Linked to Suspect Parts, Improper Maintenance" on page 18.)

In Fort Lauderdale, Florida, U.S., special agents for the U.S. Department of Transportation (DOT) Inspector General's (IG) office examined a broker's suspicious brake parts stockpiled for use on a Boeing 737 jet.

At nearby Fort Lauderdale-Hollywood International Airport, two flight computers valued at more than US$250,000 were stolen from a United Airlines jet, destined to be hawked for a fraction of their worth on a thriving black market that specializes in stolen and counterfeit aircraft parts.

In increasing numbers, unapproved, counterfeit, defective and even stolen aircraft parts are finding their way into airline and general aviation fleets.

The term "bogus parts" has a deep and ominous resonance in the language of the aerospace industry, especially since the end of World War II, when surplus parts flooded the market. But the term, while in widespread use, actually refers to several distinct categories of aviation parts.

Bogus parts can range from dangerous substandard components and blatant counterfeits to safe (airworthy) but "unapproved" parts, which can simply mean that Federal Aviation Administration (FAA) paperwork regulations were not followed to the letter. Subcontractors for FAA-approved manufacturers, for example, sometimes overproduce a part, then offer the overruns at a discount to brokers and repair stations, bypassing the strict quality control systems required by the FAA. The FAA shuns the term "bogus parts," preferring instead to classify aviation parts into two broad categories of "approved" and "unapproved" parts.

Bogus or unapproved parts amount to only a fraction of the millions of legitimate and approved parts used in aircraft maintenance. Bogus parts are often

Bogus Parts: The term “bogus parts” has come to refer to a number of aircraft parts categories, ranging from properly manufactured parts that lack required documentation to defective and deliberately counterfeited components.

Unapproved Parts: The U.S. Federal Aviation Administration (FAA) considers all aircraft parts not made under proper FAA approval and according to designated standards to be unapproved parts (not produced in accordance with U.S. Federal Aviation Regulations [FAR] Part 21.305 or repaired in accordance with FARs Part 43). This is a broad classification that includes counterfeit parts, stolen parts, production overruns, parts that have exceeded their time limits, approved parts improperly returned to service and fraudulently marked parts.

Counterfeit Parts: Aircraft parts that are not produced under FAA approval are often found to be of inferior quality although they are marketed as genuine.

Approved Parts: These parts conform to FAA-approved production standards (FAR 21.305). They can be approved under a parts manufacturer approval (PMA), under technical standard orders (TSOs), in conjunction with type-certification procedures, through FAA-administrator approval or by conforming with recognized industry specifications.

Life-limited and Time-expired Parts: Aircraft parts that have predetermined service lives become “timed-out” and no longer serviceable after they exceed these prescribed limits, which vary depending on the part and its function on the aircraft. Scrapped time-expired critical parts have been linked to several fatal aircraft accidents.

difficult to detect once they are installed on aircraft. Testing to determine the authenticity of suspect parts often destroys them in the process.

But once installed, such parts can lead to catastrophe. After a painstaking investigation, the Aircraft Accident Investigation Board (AAIB) of Norway determined that the chartered Convair crash was caused by substandard parts and poor maintenance that led to a complete disintegration of the aircraft’s empennage [the complete tail section].[1]

“This is the first commercial aircraft accident with this great loss of life that has been linked directly to a suspect part,” said Thomas Haueter, an accident investigator with the U.S. National Transportation Safety Board (NTSB) who participated in the Convair accident investigation.[2]

The Norwegian AAIB report said that locking pins [bolts] and sleeves of inferior quality “that did not comply with the specified values for hardness and tensile strength” had been installed in the empennage. Vibration, excessive wear and metal fatigue caused them to fail. Then, parts of the tail failed and sent the plane plunging out of control from its cruising altitude of 22,000 feet (6,710 meters).

The origin of the suspect pins could not be traced because the repair station that installed them in 1986 did not have a parts and supplier registration system at the time, the Norwegian report said. The pins cost US$148 each, the sleeves $135 and the washers $20.

In the Fort Lauderdale brake-parts case, extensive testing determined that a shiny-new copper-colored brake lining cup was a fraud of such poor quality that it would cause excessive wear on an aircraft’s brake assembly. At best, such a part would increase airline maintenance costs. At worst, excessive wear could cause brakes to pull to one side when applied in an emergency, sending the aircraft careening out of control.

More than 100,000 of the brake parts, illegally stamped with the same serial numbers as those made by an approved U.S. supplier, were shipped to the Florida parts broker by a German manufacturer.

U.S. agents from the Department of Transportation (DOT), the U.S. Federal Bureau of Investigation (FBI) and the U.S. military have been involved in more than 200 bogus parts investigations in the United States. Investigations are also being conducted in Europe, Canada and the United Kingdom, where unapproved parts (tail rotor shaft nuts) have been linked to a recent fatal helicopter crash, DOT officials said.

DOT officials said that they have obtained more than 60 indictments and 40 convictions thus far and expect that number to double after pending investigations are complete.

Agents have seized scores of bogus jet engine components, brake assemblies, poor quality bolts and fasteners, defective fuel and flight systems parts, unapproved cockpit instruments and flight computer components that are critical to flight safety.

Investigators have also found cracked and worn junk parts that had been welded and painted to appear new. Suspected operations have ranged from small aircraft repair stations to parts distributors for transport-category aircraft.

Counterfeit parts have been a major focus of the IG's investigations. "There is big money in bogus parts," said Tom Bezanson, a special agent in the IG's Fort Lauderdale office. "There's nothing out there they're not trying to counterfeit."[3]

He said that there are more than 200 aircraft repair stations in the Miami area alone. "As more airlines go out of business, we have more airplanes sitting around to be scavenged."

Bezanson said that his office is involved in more than 40 counterfeit parts cases.

Mary Schiavo, DOT inspector general, said that in one case a former dealer in illicit drugs told investigators that he began peddling bogus aircraft parts "because he made more money and met a better class of people."

John H. Enders, Flight Safety Foundation (FSF) vice chairman, said the spread of bogus parts is a global concern.[4]

"Expanding international trade has brought with it a corresponding increase in the mobility of parts destined for aviation use," Enders said. "Skilled craftsmen around the world now have the tools at their disposal to accurately copy or manufacture complex parts."

In addition to counterfeit parts cases, unapproved parts investigations focus on four major areas:

- Brokers that falsify parts certifications;
- Repair stations that do unauthorized repairs (and falsify maintenance records);
- Manufacturers that produce unlicensed (and

Bogus Parts Have Plagued the Aviation Industry for Decades

Although the problem of bogus parts has grown in recent years, the alarm was sounded long before large jet transport aircraft replaced their piston-powered predecessors.

In 1957, in *The Problem of Bogus Parts*, the Flight Safety Foundation (FSF) warned that the "stream of parts necessary for the maintenance and overhaul of aircraft and engines has become polluted."[5]

The FSF booklet, compiled by Joseph Chase, then FSF manager of maintenance and equipment, described the insidious growth of the bogus parts problem.

"Parts that are not airworthy, parts the source and identity of which have long been lost, parts of unknown material, fabricated by processes at variance with industry and government specifications, have entered the channels of trade," Chase wrote. "These channels are many. They include prime manufacturers, the dealers and distributors, speculators in military surpluses, overhaul agencies, repair stations and supply houses."

Chase warned: "The problem of bogus parts is serious because it is almost impossible to detect some of the phonies without extensive tests few of us are equipped to make. Many of the counterfeits are skillfully fabricated. Some carry the inspection marks and part numbers of the genuine articles. Some are even packaged like the original. Some differ from the part produced by the prime manufacturer only in the material, a difference often extremely difficult to discern. Any situation that threatens our lives and our livelihoods in spite of inspection and the exercise of our own best judgment is serious."

Chase said that several serious accidents had already been linked to bogus parts, including an accident that killed the two pilots of a twin-engine cargo aircraft and that was caused by "'non-conformities in the elevator tab controls' ... that produced pitch-down and structural failure. 'Non-conformities sometimes defective) parts; and,

- Workers who sell stolen (or surplus and used) parts to unscrupulous dealers.

Distributors are frequent victims of the lucrative stolen parts market.

AAA Interair Inc., a large Miami-based aircraft parts supplier, lost more than US$1 million of its parts inventory to theft in 1992. Eight AAA employees have been charged in connection with the thefts, which included expensive avionics equipment and hundreds of electrical components for today's high-tech jet cockpits.

The size and value of aircraft parts make them particularly attractive to thieves. A new fuel indicator about the size of a soda can for a McDonnell Douglas MD-80 aircraft, for example, costs about $14,000. A 20-pound flight management computer for a Boeing 737-300 aircraft costs about $176,000.

Howard Davidow, an aviation consultant and former president of AAA Interair, said that employee theft is a widespread problem. "You can easily steal engine components under your coat. And once they're out the door, they're nearly impossible to trace."[6]

Davidow, who has assisted federal investigators in several criminal investigations involving stolen aircraft parts, said that stolen new parts are often replaced on stock shelves with junked parts that had been earmarked for scrap. "Fixing the paperwork is easy using modern desktop computer publishing technology. The forged invoices, labels and boxes are nearly foolproof."

Howard Aylesworth, of the Washington-based Aerospace Industries Association of America (AIA), said that from a safety standpoint, "the existence of one unapproved part is a huge problem. The distributor network is so extensive and so wide open that anybody can set up shop."[7]

He said that "fraudulent and counterfeit parts represent the gravest danger to flight safety."

The FAA, which certifies aircraft parts manufacturers, repair stations and aircraft operators (but not parts distributors and brokers), acknowledges the problem, but insists that more regulation is not the answer.

in the elevator tab controls' is Washington [bureaucratic] language that means bogus parts."

He also noted the discovery on a McDonnell Douglas DC-3 of bootleg wing bolts that broke when the prescribed torque was applied. "All were bogus or bootleg bolts on which someone made an illicit profit," Chase said.

Chase traced the origin of the surge in bogus parts to the years immediately following World War II, "when vast numbers of aircraft engines were declared surplus and, almost simultaneously, the manufacturers announced that they would no longer either make or stock replacement parts for certain of these engines.

"No one worried over the situation for a long time. The number of surplus engines seemed endless, and spare parts for them were available from almost countless sources. But gradually both came into short supply, and the problem of bogus parts was born."

A short time later, Chase said, came the discovery that "many new and genuine surplus parts had lost their identity in the process of sale and resale, shipment and transshipment. Original packages had been opened and destroyed. Markings were obliterated."

Chase added: "These parts could not be guaranteed as genuine and so they were not acceptable to the U.S. CAA [Civil Aeronautics Administration, the forerunner of the U.S. Federal Aviation Administration]. As a result they were valueless to the reputable overhaul agency. This reduced the supply of usable parts, made the shortage more acute and increased the price.

"Perhaps we should have expected what happened. These orphans [uncertified parts] not only found their way into the market, but they helped create a new market, a market where integrity and responsibility are not requirements for doing business and where the only questions asked have to do with payments.

"We might have forgiven the people involved — they were dealing in genuine parts even though these parts could not be identified positively as such and so could not be used in certificated aircraft — we might have forgiven them except for what happened next.

"With business ethics weakened or destroyed, it was but one step to 'modifying' parts without benefit of engineering data, and another step to outright counterfeiting."

David Broughton, an FAA unapproved parts awareness program manager, said that the "[overall accident] record shows that bogus parts are not a big safety problem."[8] He said that regulating another whole segment of the industry will not solve the problem, adding that operators who use the parts are required to ensure that they are genuine and properly certified.

Broughton said that the agency has concentrated in recent years on increasing industry awareness and streamlining reporting about the problem. "We're doing everything we can to help people detect and report suspected unapproved parts. The FAA has been going at this at full bore for some time, and the industry has also come a long way."

Broughton said that regulations already in place are adequate. "We feel that the regulations already provide enough safeguards. Industry just needs to abide by the rules. It is industry's responsibility to make sure they are using approved parts. In the end, it's the responsibility of the purchaser."

FAA officials said that the agency does not have enough money or inspectors to monitor the nation's 2,000 aircraft parts distributors and brokers. U.S. Federal Aviation Regulations (FAR) do not prohibit the sale or distribution of unapproved parts, and investigators contend that this hampers many bogus parts cases.

The FAA's reluctance to add new rules has brought little satisfaction to many in the industry who have long contended that the only solution is to regulate parts distributors and brokers.

AIA and other industry groups first recommended regulation of parts distributors in 1978, and in 1988 AIA again asked the FAA to tighten rules governing the sale and distribution of parts.

Victor Brennan, civil air attaché with the British embassy in Washington, D.C., said that unapproved parts are of concern in the United Kingdom and Europe, but that the problem has not reached the same proportions as it has in the United States.[10]

"The U.K. [and Europe] licenses and regulates distributors," Brennan said. "There is an unbroken line of traceability in the system."

Chase said that bogus engine parts, including gear assemblies, piston pins, drive gears, exhaust valve guides, bushings, link pins and oil screen spacers, were widespread. He said that the bogus parts were subject to or created excessive wear on engines.

In 1964, Chase expressed concern again about the proliferation of bogus parts in the FSF booklet *Bogus Parts: A Continuing Threat to Safety in Aviation*.[9]

"Many of the difficulties remain unchanged," Chase said. "One very troublesome thing about bogus parts available today is that they are often marked with the ... part number of the original manufacturer and represented by the supplier as 'Surplus, New, Serviceable.' Their record has been anything but reassuring. Deviations from the conditions represented run the full scale from honest mistakes ... to outright fraud."

Chase said there was an alarming increase in the number of "modified" parts, including critical engine parts.

"The modification of parts without fully meeting all requirements for material, hardness, coefficients of expansion, imposed loads, and other governing factors must be considered dishonest and dangerous," he said. "It is a kind of counterfeiting, done without regard for possible catastrophic results."

Chase said the situation has been made more difficult by sales of surplus parts by U.S. government agencies at a fraction of their purchase price.

He said surplus antifriction ball and roller bearings were especially troublesome.

"Many of these bearings were not designed for use in critical applications," Chase said. "At the time they are offered for sale as surplus, many are obsolete, deteriorated, dirty or damaged, but the names of aircraft supply houses frequently appear on the sales abstracts, and it would naturally be assumed that the bearings they purchase are destined for a place in aviation."

Chase concluded: "Bogus parts continue to be a threat to aviation safety. We suggest that an aircraft operator's best protection is an unwavering suspicion of any part that might be unairworthy, coupled with a decision to buy only from the prime manufacturer, from his authorized dealer or distributor, or from a maintenance agency he knows will serve him well and honestly in his best interests."

Michael Rioux, vice president of engineering, maintenance and material for the Air Transport Association of America (ATA), said that distributors are also registered in Canada.[11] To obtain a license, prospective distributors must submit documentation proving that they can operate such a business in accordance with Canadian aviation standards, he said.

Rioux, the AIA's Aylesworth and other industry analysts argue that a similar system would work in the United States. Said Aylesworth: "Right now we really don't know what's out there. We have to make sure that these parts are documented and traceable."

ATA's Rioux said that adding third-party audit requirements to distributor registration would be even more effective.

We're at the end of the chain," Rioux said. "It just does not make sense [for the FAA] to let [suspect] parts drift through the system and when they get to us say 'Let's check it.' All you need is just one unscrupulous dealer and you are stuck."

The thousands of parts used on modern aircraft are subject to a variety of standards and controls. FAR Part 21.303 requires that "no person may produce a modification or replacement part for sale for installation on a type-certificated product unless it is produced pursuant to a parts manufacturer approval (PMA)," which is issued by the FAA. PMA holders are subject to rigorous testing and inspection standards.

Approved aircraft parts are those produced under PMAs manufactured in accordance with FAA standards (TSOs) and in conjunction with type-certification procedures. FAA-issued TSOs detail absolute and minimum performance standards for parts used on civil aircraft, including avionics, batteries, materials and other products.

FAA Advisory Circular (AC) 20-62C says that approved parts can be identified by:[13]

- An airworthiness approval tag that identifies a part that has been approved by FAA-authorized representatives;
- An FAA-issued TSO number and identification mark;
- An FAA/PMA symbol "with the manufacturer's name, trademark or symbol, part number, and the make and model of the type-certificated product on which the part is eligible for installation stamped on the part";
- A shipping ticket, invoice or other document that provides evidence that the part

A 1990 FSF survey noted the "growing frequency and severity of the bogus parts issue." It added: "The threat to aviation safety posed by bogus parts is a global problem."

In a related effort in 1990, FSF joined with the International Federation of Airworthiness (IFA) in preparing three position papers calling for increased industry awareness of issues relating to airworthiness assurance, international certification standards and standardization of airworthiness records for the transfer of aircraft.

"There is a need for increased international awareness of aviation industry activities and directed actions in the technology of continuing airworthiness," the first position paper said in June 1990.[12] "To achieve this, there must be more and better communications worldwide among manufacturers, the airline industry and their regulatory authorities."

The position paper noted that in some parts of the world, "maintenance actions necessary to ensure continuing safe operations are not always being accomplished or properly administered."

In the second position paper, IFA and FSF called for an "international cooperative effort to develop worldwide aviation standards for aircraft certification, maintenance and operations."[14]

The position paper said there was a need for "consistent levels of safety" in those areas.

The third position paper concluded that aircraft transfer documentation requirements should be consistent worldwide because expanding operations of both new and used aircraft are taxing the capabilities of regulatory authorities.[15]♦

was produced by an FAA-approved manufacturer; and,

- A certificate of airworthiness issued by a [non-U.S.] government [to facilitate import and export of aircraft].

The FAA defines unapproved or bogus parts as "any part, component, or material that has not been manufactured in accordance with approved procedures in FAR Part 21.305 or repaired in accordance with FAR Part 43; that may not conform to an approved type design; or may not conform to established industry or U.S. specifications (standard parts). Such unapproved parts may not be installed on a type-certificated product, unless a determination of airworthiness can otherwise be made."

[An AC, which is currently under FAA legal review and is designed to replace AC 20-62C, includes guidance on how to destroy unserviceable parts so they do not find their way back into inventories as unapproved parts.]

Unapproved parts, according to the FAA definition (AC 21-29A), can include "'counterfeit' or fraudulently marked parts or material, parts shipped directly to users by manufacturers, suppliers or distributors who do not themselves hold production approvals for the parts, and have not been authorized to make direct shipments by the manufacturers with the production approvals (e.g., production overruns), and parts that have not been maintained or repaired in accordance with [federal regulations] or that have been maintained or repaired by persons not authorized to perform these functions."[16]

Sarah MacLeod, executive director of the Aeronautical Repair Station Association (ARSA), said that sloppy business practices have contributed to the recent surge in unapproved parts.

"More regulations are not the answer," MacLeod said. "Tight record-keeping is the key to having an adequate chain of documentation for the users of aircraft parts."[17]

But David Wadsworth, executive director of the Professional Aviation Maintenance Association (PAMA), said that government and industry share the blame for the magnitude of the unapproved parts problem.

Parts from Vietnam Graveyards Haunt Today's Helicopters

Bogus parts pose a special risk to helicopters, whose complex systems and operational rigors make them especially vulnerable to substandard critical parts, industry officials said.

"We definitely have a serious problem," said Frank L. Jensen Jr., president of the Helicopter Association International (HAI).[18] "The problem is aggravated by the amount of surplus military parts on the market."

As their counterparts elsewhere in the aviation/aerospace industry, helicopter manufacturers, operators and repair stations often face difficulty identifying unapproved, counterfeit and stolen aircraft parts.

The scope of the problem ranges from otherwise airworthy parts whose documentation does not comply with U.S. Federal Aviation Administration (FAA) requirements for them to be declared "approved," to counterfeit and used (timed-out) parts that have been altered to appear new.

"The industry is working with the FAA to find ways to improve the traceability of aircraft part records," said Pamela Charles, HAI's director of heliports and technical programs.[19] "This is tremendously important because there are so many [flight] critical parts on helicopters."

Junked parts are often sold in huge lots to dealers as scrap. Some of those parts, including rotor blades and critical rotor assemblies, later find their way back into helicopters when they come into the hands of brokers who peddle bogus parts.

Giffen Marr, chief of civil certification and regulatory requirements for Bell Helicopter Textron, said that the U.S. Department of Defense is a major contributor to the unapproved parts problem in the helicopter industry.[20]

"A lot of these timed-out [parts critical to flight safety with useful life limits] and junked parts are not destroyed when they're scrapped," Marr said. "And you can be sure that the bad guys are going to deal with the parts most critical to flight because they bring the most money."

Marr (along with others in the aerospace industry) said that parts distributors and brokers should be licensed by the FAA. FAA inspectors have no authority to inspect brokers under current regulations, he said.

"The good brokers have no objections to licensing because they are willing to keep up with the paperwork," he said.

Bill Parker, chief of parts integrity in Bell's product assurance engineering division, said that the military (but not the FAA) requires that timed-out main rotors and tail rotors be destroyed before they are scrapped.[21]

"But I can tell you they don't always do it from the calls I get," said Parker, who oversees Bell Textron's bogus parts hotline.

Parker said that he received more than 300 bogus parts-related calls in 1993, of which 144 concerned "significant parts that should not be used."

He added: "Unfortunately, a lot of people don't call."

Worse, Parker said, some unethical brokers have called the hotline in an attempt to glean information on certain parts to help them forge paperwork for the illicit parts.

Parker said that time-expired rotor blades are often sold with paperwork listing them as used, but still serviceable.

Unapproved parts also find their way into the commercial aviation market from "breakout suppliers" who manufacture parts under contract to the military, Parker said.

"For example," said Parker, "the U.S. Army contracts with smaller companies to make parts for the military versions of the helicopter. By this time, the Army usually owns the drawings for these parts.

"Most of the time this is not a problem as long as the parts stay in the military. But if they wind up in the commercial market, they are unapproved parts."

"For years, the FAA did not vigorously enforce the regulations, and industry failed to do its part," Wadsworth said. "Now, more rigorous FAA enforcement is putting aviation maintenance technicians in an untenable position."[22]

Wadsworth contended that if airlines and maintenance technicians obey FAA regulations to the letter, a "substantial amount of parts" will be found to be technically unapproved.

"There are millions of parts out there in inventories that are technically unapproved because they lack proper documentation, even though we know that many are safe [airworthy]," Wadsworth said. "Maintenance technicians bear a tremendous burden because they are the people who have to sign for the parts and the work.

"The maintenance technician is in the middle. If he applies the regulations strictly, he may end up condemning a large part of his employer's parts inventory, which amounts to a considerable investment. If he doesn't, he could lose his license and his livelihood."

Wadsworth said that the FAA needs to provide maintenance technicians with a "step-by-step procedure to trace the history of parts that have holes in their pedigrees."

He added: "That procedure, if followed, should also protect technicians even if it is later determined that a part somehow got into the system improperly. Current FAA guidelines are inadequate for this purpose."

While there is still no evidence that bogus parts have caused large jet transport category crashes, accident investigation experts said that such parts could have gone undetected in some crash investigations.

"It's possible for an aircraft to suffer so much fire and impact damage that we couldn't tell if a bogus part was a factor," said Bernard Loeb, director of the NTSB's office of research and engineering.[23] He added that a variety of factors can cause parts to fail, including corrosion, wear, poor or improper maintenance, or production glitches that slip by quality control inspectors.

Bogus parts have been documented as factors in several recent fatal general aviation fixed-wing and helicopter accidents, according to NTSB statistics.

The NTSB's accident data base lists 14 incidents/accidents linked to bogus parts between 1984 and 1992.

According to NTSB reports, bogus parts accounted for several emergency landings and four fatalities.[24] Bogus parts found in these occurrences included faulty fuel filters and fuel lines, substandard bushings on electric fuel booster pumps, a bogus propeller pitch control cam and counterfeit landing-gear components.

The most serious passenger-carrier incident listed in the NTSB reports occurred in 1990 and involved a four-engine de Havilland Dash 7 commuter aircraft with 42 passengers on board. The aircraft's nose gear collapsed on landing and an investigation determined that a bogus part had been installed in the nose-gear down-lock actuator, which jammed when the flight crew attempted to lower and lock the gear. The aircraft skidded to a stop on the runway. The passengers were evacuated without injury.

Vigilance in the repair hangar has also averted potential inflight disasters.

In 1991, a United Airlines mechanic discovered a suspect engine-bearing seal spacer and returned it to Pratt & Whitney, the engine manufacturer.

Pratt & Whitney tested the $500 metal ring, which keeps rotating engine blades and disks separated in the JT8D engine, and determined that it was one-third as hard as it was supposed to be and would have failed after about 600 hours of use instead of the 6,000 hours of wear that a genuine part was designed to withstand.

Had such a spacer been installed on an aircraft, it could have resulted in an engine shutdown or fire, Pratt & Whitney officials said.

Another 30 bogus spacers were found after the company alerted its customers. The JT8D is the most widely used jet transport engine and powers Boeing 727s, 737-100s and 200s, and McDonnell Douglas DC-9s and MD-80s. About 14,000 JT8D engines are in service.

John Gilbert, manager of quality management and

Bell's bogus parts hotline has been in operation for more than 10 years. The company has also published several booklets identifying bogus parts that have been found on the market.

Bogus helicopter parts identified in the booklets include tail-rotor drive shafts, clutch drums, tail-rotor attachment bolts and other components. Several of these faulty parts led to fatal crashes, Bell officials said.

Commercial helicopter aviation may also be threatened with the legacy of U.S. involvement in the Vietnam War, some industry analysts claim.

In an article in HAI's *Rotor* magazine, aviation consultant and former federal agent Ray Robinson said that many of the timed-out parts being found were manufactured during the Vietnam War era.[25]

"Many of these parts undoubtedly came from the almost 6,000 helicopters destroyed or captured in … Vietnam," Robinson said. "These components were almost certainly entered into U.S. commerce in the mid-1980s and continue to be imported into the U.S. even today."

Robinson also expressed concern about selling used (but intact) military parts for scrap.

"These very same unscrupulous aircraft parts dealers who trafficked with Vietnam purchase these flight components as scrap for a pittance, forge the historical service records and sell these components as 'like new,'" Robinson said.

He said that scrap components bought from the military for as little as US$1 can be resold for about $1,000 to unwary buyers around the world.

A Dec. 15, 1993, HAI's *Maintenance Update* underscored the importance of changing the aviation record-keeping system to provide better traceability for parts.[26]

HAI said that Textron's Hydraulics Research Division (HR Textron) had recently discovered several cases of unauthorized repairs of flight-control actuators for the Bell 212 and 206B model helicopters that HR Textron said "could cause catastrophic loss of control and loss of aircraft and/or lives."

One unauthorized repair was found on an idler link for a Bell 212 main-rotor actuator, the Textron report said.

"The part had been drilled out to an oversized condition and press fit with bushings," the Textron report said. "The part thickness was insufficient to hold a bushing, and the press fit was so loose that movement was detected with finger pressure. Needless to say, the rework procedure was not authorized. If these bushings had vibrated loose in flight they could have jammed the mechanical stops and caused complete loss of main-rotor control."

An inspection of work performed on the Bell 206B found that main-rotor actuator rod ends had been "built up with chrome plating to reduce the size of pivot holes worn beyond use."

The Textron report said that "while the plating restored the holes to nominal size, the hard chrome used to perform the operation was susceptible to flaking and chipping when used as a bearing surface. If the plating had chipped away from the pivot-bolt hole, reduced or [a loss of] pilot control authority could have resulted."

Maintenance Update concluded: "In each [of these incidents], the operators, and subsequently the manufacturer, had no idea who performed these repairs, [and] there was absolutely no traceability. Without appropriate records, there is no way to identify the person or facility performing this rework to ensure that they are not currently, nor will they in future, produce any more parts like these."♦

data systems at Pratt & Whitney's East Hartford, Connecticut, office, said that the company has filed 12 suspected unapproved parts reports with the FAA in the past 18 months.[27] He said that other counterfeit parts for the JT8D have been discovered since the incidents involving the seal spacers. The counterfeit parts included gaskets, fuel heater covers and substandard bushings and pins used to secure the engine's rear bearing housing.

"The counterfeit gaskets were made out of asbestos and were being marketed as a genuine Pratt & Whitney part," Gilbert said. "We have not made gaskets with asbestos for years."

Gilbert said that the gaskets were used in breather tubes on pressurized bearing compartments in the JT8D.

"The bushings and pins were made with the right material, but were not coated to withstand the wear they would sustain," Gilbert said. He said that failure of pins and bushings could have caused an engine shutdown.

The fuel heater covers were produced without sufficient threading, allowing them to strip and loosen the cover. "This allows high-temperature air to dump into the nacelle environment," Gilbert said. "This is not the kind of thing you want to have going on."

Gilbert said that a New York man has been charged with manufacturing and selling the bogus seal spacers. No one has been arrested in the other counterfeit cases involving the pins, gaskets and fuel heater covers.

General Electric (GE) jet engines have also been affected, said John Moehring, GE's flight safety director.[28]

"We are aware of several cases where salvaged crash-damaged engine parts have been installed on GE engines during overhauls," Moehring said. "The salvaged parts had been cleaned up to look like new."

A year ago, five employees of a Florida-based aircraft parts supplier pleaded guilty to maintaining parts that were not properly certified. According to DOT records, worn-out jet aircraft engine starters (some with cracked housings) were painted and polished to appear new and were tagged with fraudulent certification numbers for use on aircraft.

The FAA a few months later ordered airlines to remove all starters purchased from another Florida-based company, Classic Aviation Inc. The starters were designed for use on Boeing 727s and 737s, and McDonnell Douglas DC-8s, DC-9s and DC-10s. An FAA airworthiness directive said that the FAA had determined that "these unapproved parts are unsafe and, if they are not removed, the airworthiness of the affected aircraft is not assured."[29]

The FAA said that the overhauled starters could have resulted in "fatigue or structural failure of the aircraft starter, which could result in an inflight fire or loss of control of the airplane."

In San Francisco, five owners of aircraft parts companies pleaded guilty in September 1992 to fraudulently certifying fasteners and hydraulic components that were intended for use on military and commercial aircraft.

Several suppliers have also been convicted of falsifying FAA safety inspection tags on counterfeit parts that have been altered and resold.

In addition, indictments were handed down in U.S. District Court in Los Angeles, California, in October charging a defunct engine and overhaul facility with supplying bogus parts to commuter airlines, commercial helicopter operators and U.S. Air Force cargo jets.

The 50-count indictment against Dixon Aircraft Components Inc., and its president, Rudolf Dixon, alleged that the company modified scrap or condemned parts and sold them to commercial customers and the government and then made false claims about their authenticity. Several of the bogus parts were traced to Pan Am Express and Hawaiian Airlines, the indictment said.

A Houston, Texas, repair-station owner was indicted by a federal grand jury in May 1993 on six charges of using bogus parts and falsely certifying that repairs were made in accordance with FAA regulations. According to DOT agents, installation of unauthorized and substandard engine and propeller parts at the repair station resulted in the fatal crash of an Ayres S2R, a high-performance, single-engine aircraft used in crop-spraying operations.

Although the FAA has rejected new unapproved parts regulations, it has launched an industry-wide awareness campaign to help operators identify bogus parts and to ensure that parts purchased are properly documented.

The FAA is conducting seminars on unapproved parts across the United States and has issued several advisories and directives to help the industry to detect bogus parts and to design strategies to monitor parts inventories. A new FAA-produced video on the subject has just been released.

Streamlining parts-certification procedures is under consideration and methods to develop

How Do I Know If the Part Is Genuine?

Certified aircraft and powerplant (A&P) technicians are required under U.S. Federal Aviation Regulations (FAR) Part 43.13 (b) to "use materials of such quality that the condition of the aircraft, airframe, aircraft engine, propeller, or appliance worked on will be at least equal to its original or properly altered condition." Technicians bear the final responsibility to ensure that the parts installed and the materials used in making a repair are genuine, are proper for the intended installation and are free of any obvious damage or defects. The question: "How can I be sure this is a good part?" The answer: "It isn't easy."

Having been an A&P for more than 40 years, and an inspector or member of the quality control management staff for a major air carrier for many of these years I am all too familiar with the problem of parts approval. I have found bogus parts during receiving inspections of parts shipments. I have experienced fraudulent repair-station work in which the component had not received the work as stated on the maintenance release tag, and I have had the unfortunate experience of participating in the investigation of a fatal accident that was eventually linked to a faulty part.

Counterfeit parts, undocumented parts, misidentified parts, unapproved parts and damaged parts are often lumped together under the term "bogus parts." The problem of bogus parts is not new, nor is it going to be easy to solve. Technicians can take several steps to ensure that parts are airworthy and to ensure that colleagues are alerted to problems. These actions include:

- Receiving inspections;
- Supplier qualification and surveillance;
- Repair/overhaul vendor qualification and surveillance;
- Use of the Federal Aviation Administration's (FAA) and manufacturers' malfunction and defect reports; and,
- Failure and reliability analysis.

voluntary third-party accreditation of parts distributors are also under study. The FAA's Broughton said that an AC is being drafted that is designed to help distributors and brokers establish a third-party audit program.

The FAA launched in September 1993 a suspected unapproved part (SUP) program that set up a framework for reporting and investigating suspect unapproved parts. The program, called for under FAA administrative order 8120.10, provides guidance to FAA personnel in processing and investigating reports of suspected unapproved parts, and established an alert system linking affected FAA offices with owners, operators and repair stations.[30]

In addition, a toll-free national FAA aviation safety hotline is available to facilitate reporting of suspected unapproved parts, and confirmed reports are entered into a national bogus parts data base.

A parts approval action team comprised of industry and government experts has been formed as part of a broad aviation rulemaking advisory committee (ARAC) effort to address air carrier and general aviation issues, including the unapproved parts problem. The parts-approval team (one of several subgroups working on issues related to maintenance and parts standards) is currently focusing on traceability of parts, including the millions of technically unapproved parts in commercial aviation inventories. The ARAC team was tasked in November and asked to deliver a report to the FAA by April 1994.[31]

Fred Workley, manager of maintenance operations for the National Air Transportation Association (NATA), said that more than three years of industry and government efforts are beginning to pay off.[32]

"We are coming up with solutions," Workley said. "A lot of people have been working on different pieces of the puzzle, and those pieces are starting to come together.

Workley, who is a member of the ARAC parts-approval action team, said that the forthcoming FAA

A detailed inspection of all parts and materials when they are received into the maintenance stores area is one of the most important steps in ensuring that bogus parts do not become part of an operation. Air carriers are required to have a receiving inspection function, but Flight Safety Foundation (FSF) aviation safety audit teams have found that all too often the receiving inspection function is only a cursory check, and it is nonexistent at many air taxi or corporate operators.

A close examination of a part will often disclose something that "just doesn't look right." Even common hardware should be checked for workmanship and specification conformity. Many manufacturers perform only random sample inspections of product batches — only one per thousand items may be checked.

I once found a shipment of critical rod end bearings whose threads had been cut undersize by simply threading a jam nut on the rod. Closer examination disclosed that the threads had been cut instead of rolled as specified on the blueprint, and a subcontractor had supplied an entire shipment to a prime contractor with this defective condition.

If a part is sold as a "bargain," be suspicious. If it looks too good to be true, it is very likely just that. Parts removed from wrecked or salvaged aircraft, stolen parts or unapproved parts that have been fraudulently identified are often advertised at bargain prices.

If possible, receiving inspectors should have access to the drawings and specification files for the parts in use. Manufacturers' specifications or blueprints will detail markings, stamps, heat-treatment requirements, measurements, etc. If there is any doubt about a part's authenticity, reject the item. Avoid assuming that the part is satisfactory just because it is needed.

Know your suppliers! Convince the purchasing department to forgo choosing aircraft parts from vendors based solely on price. If the supplier is new, visit the facility. Check with other operators who have used the vendor or talk with the airframe or engine manufacturer to confirm the vendor's good reputation before buying from an unfamiliar vendor.

An unannounced visit to a supplier's facility can be an enlightening experience. Although many good and reputable vendors started as dealers in surplus and used inventories, there are others who are nothing more than aviation junk dealers — they buy

AC updating AC 20-62C (identifying approved parts) includes language that recommends mutilation of life-limited or time-expired parts.

"This gives the people in the shop something to show to management," Workley said. "It becomes a question of whether you want to make a few extra dollars selling used parts that are still intact, and that could come back to haunt you, or mutilate them. It's a clear liability issue now."

Many airlines, concerned about the dangers of unapproved parts, have told suppliers that they will not purchase parts without thorough documentation.

Said ATA's Rioux: "Operators are very aware of the problem and they carry out extensive inspections to make sure parts are genuine."

The FAA's Al Michaels, program manager for unapproved parts in the Flight Standards Division, said that the mutilation clause is an important addition.

"We are trying to show people that cycle- and life-limited parts should be mutilated because they too often get back into service," Michaels said. "That's when people die."[33]

But he added that the clause does not apply to parts that are removed from aircraft with some time remaining. "It is still a good part if there is still time on it," Michaels said. "The key is to make sure you know where it came from and how many hours it has left if you buy it or use it."

Workley said that increased awareness among maintenance technicians and personnel in charge of ordering parts is also important.

"We need to make sure that all parts purchase orders clearly state that they are intended for use on an aircraft," Workley said. "Then no supplier can come back and say 'Gee, I didn't know you wanted that part for an airplane.' It's added protection."

Industry officials also say FAA administrative order

materials by the pound, clean parts and sell them by the piece.

Several of the prime parts suppliers have formed a consortium to ensure adherence to certain quality and performance standards.

Airlines and other operators perform quality spot checks to confirm adherence to these standards and thus ensure that all users can be assured of quality and airworthy parts.

Many technicians rely on shops that hold an FAA repair-station certificate as proof of that shop's qualifications. This can create a false sense of security.

Several years ago, a former employer was using a repair station for the majority of component repair and overhaul services. Several different components had poor reliability and after one particular unit failure, which resulted in a cancelled flight and lost revenue, I took the failed unit to the repair station. I insisted that the unit be put on the test bench to determine the cause of the failure.

One reason after another was offered why the bench test could not be done immediately. I initiated an extensive investigation that culminated in learning that this repair station was operating fraudulently. Units were being subcontracted to other shops. Work orders were falsified. In many cases units were simply cleaned and painted, with bills charged for overhauls.

This repair station was on the ground floor of the same building where the FAA regional office was located. The FAA personnel responsible for monitoring this repair station saw these people every day, yet they had no idea what was going on literally beneath their feet!

Do not rely solely on the FAA to monitor vendors. A regular, but random, system of on-site visits to vendors can ensure that you are getting what you are paying for. FAR Part 91.403 (a) states in part that "The owner or operator of an aircraft is primarily responsible for maintaining that aircraft in an airworthy condition."

If a bogus or suspect part is found, share that knowledge. The FAA malfunction and defect (M&D) reporting system is designed to collect and disseminate such data, and the system should

8130.21A, issued on Jan. 3, 1994, will improve traceability of aircraft parts.[34] The order introduces a revised FAA form 8130-3 airworthiness approval tag. Originally designed to provide a standardized format for the import and export of aviation products, the form now allows for the identification of parts and products.

"Whereas U.S.-certificated repair stations or air carriers with a continuous airworthiness maintenance program are required to have a record-keeping and quality control system, there is justification for using this form for purposes other than export," the FAA order said. "The form could also be used as a method of identifying products both new and used by owners and operators."

Said NATA's Workley: "The new form was developed with continued discussions with the international community, the FAA and industry as a way to assist in the effort against the installation of unapproved parts. In addition, this revision now harmonizes the maintenance record-keeping with maintenance requirements of other countries."

Michaels said that the new tag, which includes a new maintenance (Part 43) category, is already in use. Workley said that response to the new tag has been positive and implementation swift. "I know of more than 45 companies in the United States and Canada that are already using the new tag," Workley said.

But Workley and other industry analysts said that the issue of how to deal with a vast inventory of technically unapproved parts remains complex and contentious. Millions of dollars are at stake if expensive aircraft parts are declared unairworthy because they lack adequate documentation.

The DOT's IG office estimates that there could be US $1 billion worth of unapproved parts in U.S. aircraft parts inventories.

"Procedures need to be found that will help repair stations and operators document as many of these parts as possible," Workley said. "In some cases, information that is normally proprietary might be able to be used to trace the parts."

AIA's Aylesworth, another ARAC parts-approval team member, suggested that for some categories of parts, random (destructive and nondestructive) testing could be used to determine airworthiness.[35]

But Paul Beach, associate counsel for the Pratt & Whitney Group, said that could be difficult in many suspected unapproved parts cases.[36]

"In every inventory you are going to encounter some

be used whenever a known or suspected bogus part is discovered.

In addition to the FAA's M&D system, every airframe and engine manufacturer has its own system of collecting data on malfunctions and defects that occur on specific products. If a confirmed or suspected bogus part is found that applies only to a specific product, the manufacturer should be notified immediately. The manufacturer's program is frequently more responsive, and a manufacturer is usually able to take action to notify users more quickly than the FAA.

Even though the basic reliability of your aircraft may be good, you should not ignore a premature failure or malfunction of a component. Request a teardown report from the vendor on every prematurely removed component, and include a request to return any faulty parts to you. This practice will enable you to monitor individual failures and might disclose the presence of bogus parts within a component. Findings should be reported to the FAA and the manufacturer.

Similarly, a routine program of reliability analysis of system and component operations will focus attention on repeat or chronic malfunctions. Any indication of chronic problems is reason to suspect bogus parts and to initiate an in-depth analysis.

Always adopt an attitude of reasonable suspicion. Every part is suspect unless it can be proved genuine.

In the final analysis, the technician is charged with the responsibility to "use materials of such quality that the condition of the aircraft, airframe, aircraft engine, propeller or appliance worked on will be at least equal to its original or properly altered condition."♦ — *Robert A. Feeler, FSF Manager of Safety Audits* parts that you just can't say if they are good," Beach said. "If you have 1,000 parts in the bin and the documents say 990 are OK, how do you decide which ones to test? That's the concern air carriers have raised in the course of the ARAC work. There are a lot of things we still don't know."

Beach also expressed a common fear among aircraft and aerospace manufacturers. "The fundamental concern of every manufacturer once its products are in use is that if the product fails, your name is still on it even if years later an investigation determines somebody else's part caused it."

European groups are also struggling with the problem.

"We are making bogus parts our top safety theme for 1994," said Oliver Will, a spokesman for the Cockpit Association, a German organization that represents 4,000 professional pilots and flight engineers.[37] "While we cannot say that accidents have happened [in Germany] because of the problem, we are concerned that the German aviation authorities are not taking action."

Will said he feared that airline cost-cutting measures in the wake of record losses could aggravate the problem.

The FAA's Michaels admitted that solutions will be difficult.

"The situation is so complex," he said. "We are looking at all kinds of parts, from critical to noncritical, that involve many different operations. There's no one answer for all the operators."

The FAA will not have to look far to encounter the problem. A DOT audit determined that even the FAA's fleet of 62 aircraft has an unapproved-parts problem.[38] The audit found that of the $32 million in aircraft parts stocked at an FAA facility in Oklahoma, about 39 percent were not approved parts. Many parts were not traceable to their approved manufacturers, which is required by FAA regulations, according to the DOT audit. The FAA disputed the audit's findings, contending that the criteria used to determine the status of the parts were flawed.

AIA's Aylesworth said that while progress is being made, the problem will not be solved until broader

Regulations Define Parts Approval Categories

U.S. Federal Aviation Regulations (FAR) Part 21, Certification Procedures for Products and Parts, outlines regulatory guidelines for approved parts:

- FAR 21.125, "Approved Production Inspection System (APIS)";
- FAR 21.143, "Production Certificate (PC)";
- FAR 21.303, "Parts Manufacturing Approval (PMA), Standard Parts";
- FAR 21.305, "Approval of Materials, Parts, Processes, and Appliances";
- FAR 21.500, "(Import) Approval of Engines, Propellers";
- FAR 21.502, "Materials, Parts, and Appliances"; and,
- FAR 21.605, "Technical Standard Order Authorization (TSOA)."

Authority and responsibility to repair and install approved parts is regulated by the following:

- FAR Part 43, "Maintenance, Preventive Maintenance, Rebuilding, and Alteration";
- FAR Part 121, "Certification and Operations: Domestic, Flag, and Supplemental Air Carriers and Commercial Operators of Large Aircraft";
- FAR Part 127, "Certification and Operations of Scheduled Air Carriers with Helicopters";
- FAR Part 135, "Air Taxi Operators and Commercial Operators"; and,
- FAR Part 145, "Repair Stations."♦

Source: U.S. Federal Aviation Administration and more stringent parts inventory audits and documentation safeguards are put in place. Such efforts would reduce the flow of counterfeit parts and help solve the problem of technically unapproved parts, he said.

"We will never completely eliminate the potential for people to slip counterfeit [or unapproved] parts into the market," Aylesworth said. "But we can create an environment in which it will be extremely difficult to do so."

ATA's Rioux said solutions must be found that ensure high safety standards while protecting operators.

"If you suddenly took all of the technically unapproved parts out of the system, a lot of airplanes would be grounded," Rioux said.

Rioux warned that operator vigilance may not always be enough to ensure that bogus parts are not installed on aircraft.

"We've been lucky. So far we've managed to catch most of the counterfeit parts. But it just takes one to sneak through. And if it causes an accident, I guarantee we will have regulations in a heartbeat."♦

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Fatal Convair Crash Linked to Suspect Parts, Improper Maintenance

An exhaustive investigation conducted by the Aircraft Accident Investigation Board of Norway found that several safety issues, including suspect parts, improper maintenance work and documents, and aging aircraft, were part of a chain of events that led to the accident.

Editorial Staff Report

The installation of substandard empennage parts in a Convair (CV) 340/580 rendered the aircraft unairworthy for its entire three-year period of operation in Norway before it plunged suddenly into the sea, a Norwegian accident investigation says.

The post-crash investigation revealed a range of safety concerns, from airworthiness and suspect parts to serious maintenance performance and documentation issues involving aging and significantly modified aircraft, according to a report by the Norwegian Aircraft Accident Investigation Board (AAIB).[1] All 55 people on board the Convair were killed.

Following the crash of the chartered Partnair CV 340/580 on Sept. 8, 1989, at about 1638:30 local time, an exhaustive search and rescue operation was mounted 10 miles off the Danish coast.

When rescue personnel arrived at the scene, they found 31 bodies and wreckage floating in the sea, according to the AAIB report released in early 1993.

"Later, the rest of the wreckage was found scattered over several square kilometers of the seabed," the report said. The AAIB said that another 19 victims were recovered in the area and that five people remained missing.

The AAIB said that analysis indicated that "there were no clear signs of the aircraft having completely broken up before impact with the water. However, there were data that could point to a partial breakup, mostly likely in the altitude range of 5,000 [feet] to 10,000 feet [1,525 meters to 3,050 meters]."

Autopsies of the victims determined that 15 of the 31 passengers found floating in the sea immediately after the crash had "skin impressions from the seat belts, indicating that they must have experienced a sudden deceleration while in their seats. Two of the victims had small puncture-like lesions on the upper torso. These findings were also analyzed by police experts. They did not interpret these injuries as being a result of a detonation or explosion, but rather as a shower of metallic fragments from the breakup of the fuselage. [More] than three-quarters [of these victims] sustained an injury pattern previously observed in free-fall accidents."

The AAIB report added: "The copilot in the starboard [seat] sustained severe injuries to his right hand. These injuries corresponded to those commonly seen in persons gripping aircraft controls at impact. An unbroken toothpick with both ends pointed was found in his stomach. It is assumed that the only way to swallow such an object is by reflexive action caused by sudden shock or surprise. It is therefore assumed that the crew experienced a sudden deviation from normal flying conditions."

The report said that Swedish radar monitored the accident aircraft for the last time at 1437:43. "The radar recording ended abruptly on the Swedish radar screen, which, according to Swedish experts, indicated a steep descent."

Radar stations also recorded falling and drifting objects after the accident aircraft had disappeared from the screen, the report said.

The AAIB concluded that the objects recorded by radar "must have been one or more pieces of metallic honeycomb in the shroud doors on the vertical fin."

Several radar stations also recorded indications of a rapid descent. The times given in the radar reports are in universal time coordinated (UTC), which was plus two hours local time when the accident occurred.

"From 1428:00 hours to 1432:36 hours there were several recordings of 21,900 feet (6,679.5 meters). Twenty seconds later the [aircraft's transponder Mode C] recording was 21,800 feet (6,649 meters). There was a subsequent interval until 1438:03 hours, when the final recording was made. The altitude of the aircraft was then given as 11,200 feet (3,416 meters)."

According to the AAIB report, steady recording of altitude ended at about 1437 hours. "This indicated that a marked drop in altitude began at this time."

The report said that about 90 percent of the wreckage was recovered. Depths in the area of the crash site ranged from 295 feet to 131 feet (90 meters to 40 meters), it said.

After extensive analysis of the wreckage, the AAIB determined that "undampened oscillations [flutter] developed on the fixed surfaces and control surfaces of the aircraft tail" and that the oscillations were "initiated by abnormal wear and tear on parts that were not manufactured in accordance with the aircraft specifications supplied by the manufacturer."

["Flutter is defined as a high-frequency oscillation of structure under interaction of aerodynamic and aeroelastic forces; basic mechanism is that aerodynamic load causes deflection of structure in bending and/or twist, which itself increases imposed aerodynamic load, structure overshooting neutral position on each cycle to cause load in opposite direction. Distinguished by number of degrees of freedom (bending and torsion of wing, aileron and other components are considered separately), symmetry across aircraft centerline, and other variables."[2]]

… the vertical stabilizer was attached to the fuselage with "pins and sleeves that did not comply with the specified values for hardness and tensile strength …"

The AAIB said that the vertical stabilizer was attached to the fuselage with "pins and sleeves that did not comply with the specified values for hardness and tensile strength and were therefore not airworthy (Figure 1, page 20)."

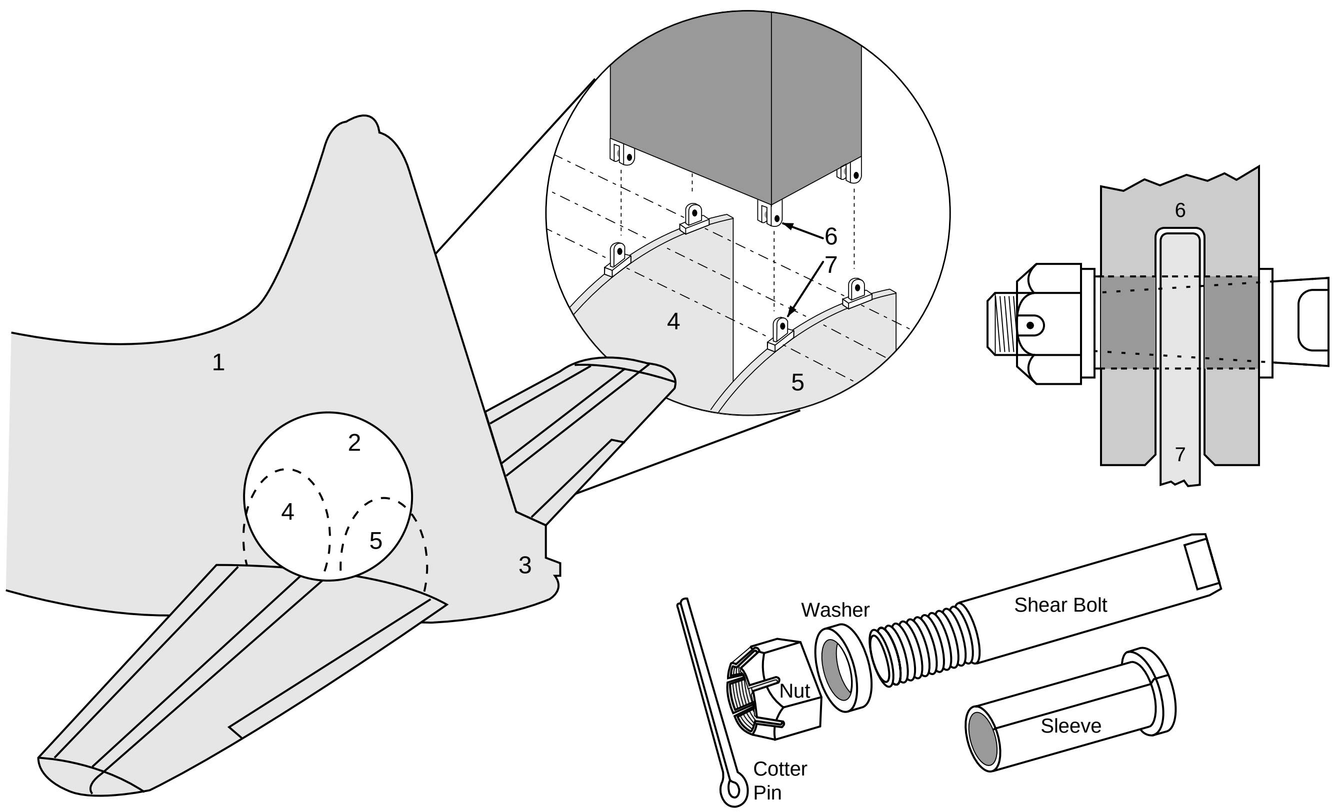
While in cruise at an altitude of 22,000 feet (6,710 meters), "vital parts of the tail structure failed and caused loss of control" of the aircraft, the report said.

The report added: "The abnormal wear was not properly repaired during the last maintenance overhaul carried out on the aircraft. [The wear in the fin attachments led to vibrations developing into flutter.] Undampened oscillations in the elevator contributed to the complete breakdown of the aircraft tail.

"The aircraft auxiliary power unit (APU) was in operation at the time of the accident. The front support of the unit had not been made in accordance with the specifications issued by the manufacturer [was of inferior quality] and the support had failed prior to impact. The fact that the APU was operating with a defective support had an influence on the oscillations in the empennage [the complete tail section]."

The problems in the APU's front support went undetected because of "faulty, out-of-date

View of the Convair 340/580 Tail Section



Source: Aircraft Accident Investigation Board of Norway

1	Dorsal fin	3	Tail cone	6	Attachment fitting in vertical stabilizer
2	Vertical stabilizer interspar box	4,5	Bulkheads supporting stabilizers	7	Attachment fitting on fuselage bulkhead

Figure 1

maintenance instructions and inadequate maintenance procedures," the report said.

Moreover, the AAIB said that maintenance instructions for the U.S.-built aircraft "did not reflect the current aircraft configuration. The airworthiness requirements for the aircraft were not met while it was in service in Norway because the minimum equipment list (MEL) and maintenance instructions had not been updated to include systems and components currently installed in the aircraft."

The report said that the aircraft's airworthiness at the time it was transferred to Norway from Canada was based on a Canadian certificate of airworthiness. Because the maintenance instructions were not complete, "the basis on which this certificate of airworthiness was issued may have been unsound," the report said.

The cause of the accident was "loss of control and stability as a consequence of defects in the structure of the primary control surfaces," the report concluded.

Positions of recovered wreckage were plotted on maps and the information was sent to a research institute to identify possible trajectories for the falling aircraft parts.

There were no signs of a fire before the crash, the report said.

The report said that the accident caused the aircraft to break up "in parts of varying sizes." It said that the forward left side of the fuselage was damaged the most extensively. The wings failed symmetrically under negative G load [they failed "downward" from normal flight position], according to the report.

The AAIB said that symmetrical wing failure indicated that the "negative load must have been somewhat symmetrical around the longitudinal axis of the aircraft, and the onset of load must have been very rapid. Failure of one wing would have led to an instant unloading of the opposite wing, hence the failure of both wings must have occurred simultaneously or within a very short time span. To achieve this, the load must have increased at a high rate."

The report said it was "most unlikely that any action by the crew or a failure in the flight control systems between the cockpit and the flight control surfaces could have led to such an overload. The only explanation is that the aircraft was out of control when the wing failure occurred. Loss of control and stability to the point where wing structure was overloaded would indicate the pre-existence of a partial or complete empennage control surface malfunction."

… both pilots were "highly experienced and reputably competent in their profession."

The tail section had been broken "into many large and small parts," the report said. "These parts were found some distance from each other."

Analysis of the tail section wreckage determined that the elevator hinges were severely damaged, the report said. The AAIB said the front APU attachment bracket to the aircraft had a fracture that had occurred before impact with the water.

The investigation also found that the "attachment pins and sleeves of the vertical stabilizer had abnormal wear."

"In addition, the rear left pin and sleeve were loose in the bushings. The vertical stabilizer had only minor deformations in the skin, but the rudder and the top fairing had been torn off. The shroud doors, which covered the gap between the rudder and the fin, were torn to pieces. The middle layer in the honeycomb construction was separated from the skin over large areas. Marks on the remains of the shroud doors that the rudder balance weights had pounded against them in such a way that they had been torn to pieces. The rudder had broken up into several pieces.

"The tail surface had symmetrical fractures as a result of alternating loads. The skin on the remaining parts of the tail was deformed, with diagonal wave-like wrinkles. This is a certain indication of reversing torsional loads."

The report said that there was evidence indicating that the aircraft's main wheels had "been pushed upwards with great force," damaging the engines, which were mounted over the wheel wells.

Examination of the engines determined that the electrical fuel shut-off valve actuators were found closed for both engines, according to the report.

There was no evidence to suggest deficient crew performance, the report said, and "medical and technical findings revealed that the crew did their utmost to control the aircraft."

The report said both pilots were "highly experienced and reputably competent in their profession."

The captain, 59, had logged more than 16,000 flying hours, with more than 1,200 hours in type.

The first officer, 59, who also served as the company's flight operations manager, had logged more than 16,000 flying hours, and a total of 675 hours in type.

Weather was not a factor in the accident, nor was there evidence of explosives or military activity that would have posed a threat to aviation operations, the report said.

The report said that at cruise altitude, the crew had "good visibility between cloud layers with winds at 24,000 feet [7,320 meters] reported as 260 degrees at 70 knots.

"The technical investigation excluded the possibility that operations were affected by abnormal propeller or engine performance," the report said.

The investigation determined that the "loss of control occurred suddenly and without due warning."

The AAIB focused considerable attention on the aircraft's ownership and maintenance history. When Partnair purchased the aircraft, records indicated that the aircraft had had 10 previous owners at various locations in North America and Central America. The aircraft had been delivered new to United Airlines in Chicago, Illinois, U.S., in 1953.

The Convair had a total aircraft time (TAT) of 36,943 hours and 15,116 landings at the time of the crash. It had logged 1,913 hours since major overhaul in 1986.

In 1960, the aircraft's original piston engines had been replaced by Allison model 501D13 turboprop engines, and the aircraft designation had been changed from a CV 340 to a CV 340/580.

The report said that "quite a few modifications" had been made to the accident aircraft before 1986.

"In addition to the engines being replaced, the following modifications should be mentioned: the installation of the APU in the tail cone, the reconstruction of the heating and ventilation system and the modification of the alternating current (AC)-supply system in that a third generator was to be driven by the APU."

In connection with modifications made to the accident aircraft, the report surveyed problems that can arise when extensive work is performed over time under supplemental type certificates.

"These modifications were carried out in several stages, and some of them were done several times,"

"After an aircraft has been type-rated it is not unusual for an operator, maintenance organization or supplier of systems or equipment to aircraft to want to initiate extensive changes, which makes an application for a supplemental type certificate (STC) necessary. The applicant must then substantiate, to the satisfaction of the civil aviation authorities, that the modification conforms to current airworthiness requirements. Furthermore, it is a requirement that the modification neither affects, nor is affected by, earlier modifications. When inquiry is made into [an] STC previously carried out, it is apparent that this requirement may be difficult to adhere to when a number of extensive modifications have been carried out.

"A large number of extensive modifications may also create problems in other areas. An example of this is in the establishment of satisfactory maintenance routines. For type certificates, a manufacturer makes recommendations with respect to the lifetime of components and intervals between one maintenance and another. These recommendations are usually the basis for the maintenance [that] system operators seek to obtain approval for from the civil aviation authorities.

"When some or all units of an aircraft are modified in such a way that the new configuration is quite different from the original version, it is the responsibility of the operator concerned to prepare new maintenance routines and obtain approval for them. This may often require expertise that is not always available to the owners/operators.

"Problems also arise with regard to the aircraft manufacturer's responsibility for supplying, and ability to supply, operators with after-sales support. In some cases, the STC is so extensive that the aircraft changes its designation. The STC-owner then takes over the role the original manufacturer/supplier previously had in obtaining technical documentation for the use and maintenance of the aircraft. This means that there is a possibility that valuable information is not conveyed to future owners."

Modifications in the accident aircraft's 1986 overhaul included new cabin flooring and fittings for a 52-seat version, new cabin interior, new galleys, new autopilot and flight director, standardization of radio equipment and evacuation slide, new air conditioning system, underwing fuel pressure refueling and new heating and ventilation systems.

The aircraft's fuel tank capacity, maximum allowable takeoff weight and landing weight and zero fuel weight were also increased.

"These modifications were carried out in several stages, and some of them were done several times," the report said. "This meant that the aircraft was converted either to its original or to its previous configuration, and then modified once again.

"This, together with the fact that the aircraft changed owners and operators many times, resulted in the aircraft maintenance documentation deviating to a large degree from the aircraft's actual configuration. This fact presented a problem in the process of preparation of satisfactory maintenance requirements."

The report noted that more modifications were carried out on the accident aircraft "than on most of the other CV 340/580 aircraft that were, and still are in service." It said that these modifications resulted in further changes being made to several systems. Several documents were affected by these modifications. The report said that document revisions based on modifications were not complete on the maintenance schedule, maintenance manual, local repair station work card, Allison parts catalog, flight manual with checklists and the MEL.

The report added: "There were few aircraft logs available between 1953 and May 1971 and there were only a few pages found between 1970 and 1971. In May 1971 the aircraft was purchased by Servicio Aereo de Honduras (SAHSA). Many of the documents dated between 1971 and 1978 are available in Spanish."

Between September 1984 and August 1985, the aircraft was out of service and "to be found at Opa Locka, Florida"

Between September 1984 and August 1985, the aircraft was out of service and "to be found at Opa Locka, Florida," the report said. Kelowna Flightcraft Ltd. (KFC), Kelowna, Canada, bought the aircraft in August 1985. Partnair purchased the aircraft in May 1986 from KFC, which continued to perform maintenance on the Convair.

The AAIB said "three separate events" were linked to "maintenance work carried out at KFC [on the aircraft]" in 1986: "The pins and sleeves in the vertical stabilizer attachments were replaced; the APU was reinstalled with a front support of inferior design and unknown origin; and the aircraft was prepared for transfer to Norwegian registration, and for operation by a new operator, with incomplete maintenance inspection requirements."

The report said that KFC told investigators that the original supports were used when the overhauled APU was reinstalled in 1986.

An analysis of the four APU supports determined that two were intact and two were fractured, the report said.

"Metallurgical examinations revealed that the rear support had failed in overload while the front support showed signs of fatigue failure. The [front] support end fitting, which is normally a rod end with an internal spherical bearing, had been replaced by a locally manufactured design. This consisted of a square piece of iron and a threaded rod which had been welded together. The quality of the welding was poor and the wrong type of material had been used. The fatigue fracture was caused by a fault in the welding. The method used to make the support and the choice of material did not conform to the standards used in aircraft parts. The support had signs of repeated loads having been applied to it after the fracture took place."

The report added: "The air pressure duct leading from the APU to the ventilation and starting systems had repairs carried out ... that were not up to standard [in] method and technique. Several joint weldings and repairs were imperfectly done. They contained slag and pores, and some of the basic material had been only partly melted. This, among other things, had resulted in a fatigue crack about 70 mm [2.7 inches] long appearing in the duct between the APU and its outlet and regulating valve.

"Lack of documentation makes it impossible to determine the extent of the maintenance that the unit had received before the accident. Therefore, there are neither indications as to who installed the unit's front support nor as to who was responsible for its manufacture."

Referring to the empennage, the report said "maintenance records show that all four pins with matching sleeves, connecting the vertical stabilizer to the fuselage structure, were replaced during maintenance carried out in 1986. The investigation further revealed that all four sleeves plus the two front pins did not conform to the specified hardness. Their actual hardness yielded a tensile strength of little more than 50 percent of the specified value.

"The composition of the material in the pins and sleeves, as well as their dimensions did, however, conform to specification. This indicated problems in the heat treatment of the parts, resulting from a probable lack of hardening after they had been machine-worked."

The AAIB said that maintenance documents revealed that the pins and sleeves were installed according to overhaul manual specifications by KFC. It said no additional work was done on the vertical fin attachments until the aircraft returned to KFC for maintenance in 1989.

"The maintenance documents did not state the origin of the parts that did not meet the specifications. When the AAIB queried this, KFC stated that the workshop did not have a registration system prior to 1987 that would make it possible to trace the suppliers of these parts.

"In 1987 the workshop initiated a system that made it possible to trace mounted parts to both production series and suppliers. From 1984 onwards the workshop used pins and sleeves from five different suppliers. It is a requirement that the pins and sleeves be produced in compliance with the manufacturer's drawings and specifications for materials, dimensions, surface treatment, hardening and tensile strength."

… once the defective parts were installed on the aircraft, they could "only have been corrected by a precise, target-oriented inspection."

The AAIB report said that once the defective parts were installed on the aircraft, they could "only have been corrected by a precise, target-oriented inspection. Normal preventive maintenance does not reveal such deficiencies until the resulting symptoms develop."

The investigation "brought to light a history of elevator hinge problems for this aircraft type," the report said.

"The installation of turbine engines gave these problems a new dimension, as more powerful engines increased the vibratory loads on the empennage and it components. The vibrations are caused by turbulent air from the propeller slipstreams impinging on the tail surfaces. Several cases of elevator oscillations caused by defective hinges have been reported. In at least one [inflight] case the oscillations were such that, if they had been allowed to continue, they could have damaged the tail structure."

The AAIB reviewed available documents relating to elevator hinge problems on this type of aircraft and concluded that:

- General Dynamics, Convair Division, in 1954 told operators to inspect and repair hinges where necessary;

- "A review of various service reports revealed that the CV 340/440 piston-engine aircraft never had vibration problems due to worn elevator hinges. All findings of abnormal wear were revealed at maintenance";

- Service reports on turbine-powered aircraft indicated that all findings of abnormal wear resulted from vibration problems during flight. Vibrations always occurred at high airspeeds and always ceased at lower airspeeds;

- "In one reported case, the vibrations were so severe during acceleration to cruising speed from the airspeed maintained during climb that the pilot-in-command at first suspected that the vibrations came from one of the engines. He shut down one of the engines, but this did not improve the situation. He restarted the engine and decided to return to the departure airport. When engine power was reduced and the airspeed decreased to approximately 170 knots the vibrations ceased"; and,

- Fifteen out of 18 reported cases stemmed from faults in the left elevator hinges. In two cases the actual elevator was not mentioned. In one case, abnormal wear was reported in the right elevator hinges. The report concluded that "it is well known from previous experience that the hinges on the left side are exposed to the greatest amount of strain owing to turbulence caused by the air stream" from the propellers.

"Because of these vibration problems it was of great interest to ascertain what had been done with these hinges during the last D-check at KFC," the report said. "A review of the maintenance documents revealed that both elevator and rudder hinges had been inspected. The work was checked and signed for on July 18, 1989 at TAT 36,883 hours. In addition, the following was written on the document: 'No defect found/noted.'

"On the relevant SID (supplemental inspection document) card there was a remark written under the entry 'elevator and rudder hinge support structure attach flanges,' saying: 'No defects found.' The maintenance documentation described the inspection as being a sight inspection."

The report concluded: "Investigation of the elevator remains [from the accident aircraft], including the elevator torque tube, indicated that at one stage in the accident sequence the elevator had been subject to violent oscillations. The elevator hinges were found to be in a defective state. A metallurgical analysis of the hinges, the right-hand inboard hinge in particular, indicated that deformation was caused by a limited number of cycles in overload rather than long-term wear and tear. This makes it unlikely that the elevator hinges initiated the process of abnormal vibrations in the tail."

It added: "In the inner sections of the left part of the elevator, which the AAIB received in the summer of 1992, both the hinge bracket and the hinge pin were missing. The anchor nut on this side had also been torn off in such a way that the threaded portion was missing."

"… it is a strong possibility that the APU, with its weight located at the very end of the tail, and the gyroscopic effect from the rotating mass, could have affected the general vibration pattern of the empennage."

The report also noted that the left-hand alternating current (AC) generator was not functioning properly and a decision was made to run the APU generator (as the electrical power source for the left AC system) throughout the flight from Oslo to Hamburg, Germany, on Sept. 9.

On a flight the day before, the APU generator was used as substitute for the left generator for about 15 minutes after takeoff and then switched off after the aircraft reached cruise altitude, the report said. "The [accident] flight was the only one known where the APU was in continuous use."

According to the MEL, both AC generators must be operative before departure. The accident aircraft's MEL was not revised to take into account its current configuration with a third AC generator mounted on the APU. The flight operations manager (the first officer) decided that the aircraft could be operated with the APU generator used as a substitute for the inoperative left-hand main AC generator and the pilot-in-command agreed. "The decision to accept the aircraft in spite of the malfunction in the left-hand AC generator system on Sept. 8, 1989 was based on a review of the MEL for this aircraft type. The review concluded that the aircraft could be airworthy with the APU in continuous operation and the APU AC generator supplying power to the left-hand main AC system. The fact that the MEL had not been updated, and thus did not take into consideration that the [accident aircraft] had a third generator, raised questions after the accident about this interpretation of the MEL.

"Discussions the [AAIB] had with pilots and mechanics from [the operator] gave the impression that the APU generator was generally accepted as being one of the two necessary electrical power sources which had to be in operation in order to satisfy the MEL requirements. The AAIB was also informed that mention was made on the emergency checklist of the use of the APU generator. It was stated on the list that the generator was only to be used should one of the engine-driven AC generators fail. The emergency checklist is only for use while airborne. According to the normal checklist, the APU should be switched off prior to departure."

The report added: "The APU turbine section had deteriorated as a result of heat erosion and cracks. The turbine rotor had rubbed against the stator vane ring. Cracking along the circumference of the stator vane ring over a 180-degree sector had cocked the stator in relation to the rotor, thus eliminating the clearance between the stator and the rotor on one side. The turbine rotor rotates at more than 40,000 rpm [revolutions per minute] during steady-state operation. If the rubbing had initiated any vibrations, the frequency would have been very high. It therefore seems highly unlikely that it was the APU that initiated the cyclic stress exerted on the surfaces of the empennage.

"However, it is a strong possibility that the APU, with its weight located at the very end of the tail, and the gyroscopic effect from the rotating mass, could have affected the general vibration pattern of the empennage. The witness marks found on the failed front APU support indicated oscillations around the lateral axis. Elasticity in the main supports, located on each side of the APU, allowed a limited degree of motion. If this situation were to be combined with an external energy source the APU could serve as a catalyst in transforming and transmitting vibration between reacting components in the empennage."

[The report noted that KFC had placed 437.5 pounds of iron plates in the aircraft's nose section to act as ballast to compensate for the weight of the APU in the tail.]

The AAIB investigation also found rudder oscillations beyond the normal maximum limit of travel.

"When an aircraft travels at cruising speed excessive force is needed to force the rudder against the stops," the report said. "The control system is normally not strong enough to transmit this power to the rudder. This leads to the conclusion that the oscillations could not have been initiated by the crew or autopilot, or by an internal failure in the control system itself."

The aircraft's flight data recorder (FDR) suffered from increasing operational problems before the accident flight, the report said. The investigation determined that the FDR was recording only pressure altitude, airspeed and heading during the accident flight. The G-parameter was not functioning, the report said.

The cockpit voice recorder (CVR) was recovered, but had become inoperative following an increase in engine rpm before departure, the report said.

"The malfunction was caused by modifications carried out subsequent to the original installation of the CVR," the report said. "One of these modifications was carried out ... to achieve an automatic switching of the electrical source to the primary AC system when the engines were shifted to high rpm for flight. Correct voltage and frequency from the engine-driven AC generators are only available at high, constant engine rpm. This switching was carried out automatically by means of relays, while this had previously been done manually in accordance with checklists. The relays installed [on the accident aircraft] and other aircraft modified in the same way were of a type insufficiently protected from environmental factors such as dust and corrosion."

The report said the malfunction was reported to the Norwegian Civil Aviation Administration (CAA) and that it subsequently learned that the same malfunction had been discovered on other aircraft of the same type.

"Immediately before the FDR ceased operation it recorded a heading turn to the right for about three seconds, followed by a reverse to the left at an extremely high rate of more than 500 degrees [per minute].

"Since operations preceding 34 minutes FDR time were extraordinarily stable it was concluded that the aircraft was operating on autopilot when the first disturbance occurred at 34 minutes FDR time," the report said.

"Immediately before the FDR ceased operation it recorded a heading turn to the right for about three seconds, followed by a reverse to the left at an extremely high rate of more than 500 degrees [per minute].

"In four reported accidents where this type of FDR was installed [and where similar heading indications were recorded] a roll was observed by eye witnesses or was established from the relative positions of wreckage components. The [FDR] manufacturer's representative, who also participated in the design of this type of FDR, commented that an analytical assessment of the FDR and its subsystems led to the conclusion that one would have expected a radical heading change to have been recorded when the aircraft rolled. Based on this information the [AAIB] is of the opinion that the aircraft went into an uncontrolled roll to the left at that time."

The report added: "At 30:30 FDR time a heading change of 8.5 degrees to the left was recorded. At 33:40 FDR time the heading was again altered to the left by 5.5 degrees. A minute later there was an additional heading change of 5.5 degrees to the left. At approximately 35:40 FDR time a sudden, sharp change of heading to the left, greater than 12 degrees was recorded. The extent of the change of heading cannot be accurately determined because wrinkles on the foil in this area make a reliable reading difficult. There were, however, indentations that indicate the change of heading to be greater than 25 degrees. This, in relation to the time axis, corresponds to a rate of turn of approximately 500 degrees per minute."

The report said that the altitude traces recorded on the FDR show a "pronounced double line during climb, from 1,400 feet (427 meters) until the FDR stopped functioning at 36:01 FDR time."

The double line on the altitude parameter appeared for the first time about 330 flight hours before the accident, the report said. The double lines on the altitude parameter decreased after a maintenance visit to KFC in 1989, according to the report, but appeared with increasing frequency until the accident flight.

"By examining the maintenance records for the FDR and recordings from past operations it is evident that the FDR frequently malfunctioned and that the number of breakdowns increased prior to the accident flight," the report said.

…while the aircraft had been operated for an extended period with abnormal vibrations in the empennage, the vibrations "could not be distinguished from the natural vibration pattern of the empennage, and thus did not alarm the crew or passengers."

The investigation concluded that the double altitude trace on the FDR foil was an "indication that the FDR had been subject to an abnormal level of vibration."

The AAIB report added: "The empennage is generally subject to high vibration levels. This is particularly the case in propeller-driven aircraft where a high output of power creates an energy-rich slipstream, exposing the tail to turbulence.

"The FDR, which is normally installed in the tail, was designed to withstand vibrations. According to specifications, this FDR type had been tested to specified energy levels defined by frequency range and maximum amplitudes. Since no known internal failure mechanisms could have resulted in the dotted double lines, the FDR must have been subject to external sources in the form of vibrations which exceeded the test criteria level.

"An analysis of the abnormal readings, with regard to the phase of flight in which they occurred, strongly supports the hypothesis of empennage vibrations being the source of the FDR anomalies."

The report said that while the aircraft had been operated for an extended period with abnormal vibrations in the empennage, the vibrations "could not be distinguished from the natural vibration pattern of the empennage, and thus did not alarm the crew or passengers."

However, at between 34 minutes and 36 minutes FDR time, the vibrations in the tail section "assumed catastrophic dimensions" and began affecting the lateral stability of the aircraft.

"When the oscillations began, large amounts of energy were available from the turbulent air flowing from the propellers. The tail control surfaces were subject to loads in excess of design limitations, and the control linkage to the cockpit was overloaded and failed.

"At this point it must have been evident to the crew that something had happened to the tail section, and this may explain why the APU fire extinguishing system had been triggered, resulting in fuel starvation in the APU, but had no influence on subsequent events."

According to the report, the APU fire extinguisher bottle and its squib were not mentioned in maintenance documents. It said "snag cards" for the bottle and squib indicate that both were changed by KFC in July 1989. It said the reason for the changes was not given on the snag cards. Expert testing of the system determined that "when the squib was fired there was no extinguishing agent under pressure in the container."

At 35:40 minutes FDR time, the rudder jammed in a maximum left-hand deflection, the report said. The rudder then subsequently failed and was partially torn from its hinges after introducing enough yaw to initiate the rapid roll to the left, according to the report.

The investigation concluded that wear in the vertical stabilizer attachments progressed at an abnormal rate and that the wear created clearance in the joints, allowing the stabilizer to vibrate.

"The vibrations occurred with increasing frequency and lasted longer and longer into each flight as the wear progressed. No indications of abnormal conditions were evident to maintenance personnel.

"Not until July 1989, when the aircraft was in for inspection at KFC, was any sign of abnormal wear evident."

The report noted that the defective APU front support "passed through several maintenance inspections [at that time] without any comments being recorded in the maintenance records. The reason for this may have been that the current maintenance instructions were incomplete."

The investigation concluded that wear in the vertical stabilizer attachments progressed at an abnormal rate and that the wear created clearance in the joints, allowing the stabilizer to vibrate.

The report said that as part of an SID program, the aircraft's vertical stabilizer attachments were to be inspected for cracks during the July/August visit to KFC.

"The inspection was supposed to be carried out with the pins and sleeves removed so as to have access to the interior surfaces of the pin/sleeve holes. If this disassembly had been carried out as planned it would have revealed unacceptable wear on all four pin/sleeve combinations."

However, KFC decided to use ultrasonic equipment for the inspection, and did not remove the pins and sleeves, the report said.

"This procedure did not comply with the relevant maintenance instructions, and when the operator's representative, an appointed inspector, became aware of the situation, he did not approve the inspection. It was decided to postpone the inspection until the aircraft had returned to Norway. This was acceptable according to AD [airworthiness directive] Note 88-22-06, which made the SID program mandatory.

"The remaining maintenance requirements did not include any inspection of the vertical stabilizer attachments. The total operating time between replacements of pins and sleeves had not been finalized in the relevant maintenance instructions. However, according to manufacturer recommendations and maintenance intervals established by other operators, this could be as high as between 10,000 and 20,000 hours of operating time."

A sight examination of the attachments revealed that the rear right-hand pin and sleeve had rotated and that black oxide and wear particles were "weeping" from the installation, the report said. "This observation led to the replacement of the bolt and sleeve in the rear right-hand installation.

"The accident investigation revealed conditions indicating that substandard routines were being followed during the replacement. At this point unacceptable levels of wear must have been present in all four attachments, although wear was not outwardly visible in the other three. The manufacturer ... describes the procedures for replacement of the pin and sleeve in its maintenance manual.

"This procedure requires replacement of only one pin and sleeve at a time, leaving the other three installed while removing it. With normal levels of wear this is sufficient to keep the attachment being worked on fixed in the correct position. In this case, with abnormal wear in all four positions, the vertical stabilizer would have had to be unloaded and its weight taken off the mounts to ensure that it was in the correct position.

"Maintenance records did not reveal any details [about] how the work had been carried out, but there is reason to believe that the stabilizer was not unloaded. If this is the case, with the stabilizer attachment sagging in relation to the fuselage attachment, the holes would not have been concentric and there would have been problems measuring the actual diameters of the holes with the steel bushings installed. The fact that the holes were not concentric would also make it difficult to install the new pin and sleeve correctly."

The replaced pin and sleeve were scrapped before the accident, thus making a determination of the amount of wear they experienced impossible, the report said.

"Regardless of the degree of wear, it must be considered a departure from correct aviation maintenance standards to replace only one of four identical components in a vital structural system where abnormal conditions occur. The investigation clearly demonstrated the importance of this fact."

The report added: "Replacement of one pin/sleeve set resulted in a change in the structural rigidity. This in turn changed the natural frequency of the system of which the vertical stabilizer and attachments were a part.

"The replacement of one pin and sleeve set changed the vibration pattern in the empennage. On the flights immediately following the maintenance it appeared to be an improvement, registering vibrations on the FDR foil on only one in nine flights. On subsequent flights, however, this development took a serious turn for the worse. These same vibrations were registered on 15 of the final 24 flights. This seems to indicate that the replacement of one pin/sleeve set actually aggravated the situation by changing the natural frequency of the stabilizer.

"Apparently there was no reaction to the fact that the maintenance documentation still did not cover the inspection of the APU positioned in the tail section."

The AAIB report said there was evidence that maintenance routines were disrupted in the days before the accident.

"During the final few days before the accident ... [the aircraft's] scheduled flight program had a negative effect on its maintenance program. [Partnair's] strong desire to complete as many flights as possible resulted in a delay in the correction of reported faults. The reason for this may have been the operator's critical financial situation."

Partnair had financial problems at the time of the accident and filed for bankruptcy shortly after the accident, the AAIB report said. The accident aircraft's departure from Oslo was delayed more than an hour, in part because a catering company had suspended Partnair's credit.

Based on its investigation, the AAIB concluded that the accident aircraft "was not airworthy after May 1986," when the substandard pins and sleeves were installed.

The report said that during its three-year service in Norway, maintenance responsibility for the aircraft was divided between the operator and a local repair station, both of which were under the supervision of the Norwegian CAA.

After the accident, the report said, the "parties involved had differing opinions on how responsibility had been administered."

The AAIB said it "considered the possibility that the working relationship between the three organizations could have played an important part in the aircraft's state of maintenance deteriorating to a point where it caused an accident."

After the accident, the report said, the "parties involved had differing opinions on how responsibility had been administered."

The report said the local repair station in Oslo sometimes subcontracted maintenance out to KFC, which was also approved by the Norwegian CAA, because of a lack of capacity.

"On the whole, this situation gives a picture of an arrangement in which heavy demands were made on planning, administration, communication and control," the report said. "Assessment of these circumstances leads one to the conclusion that in order to have aircraft with the same status of [the accident aircraft] operating safely, responsibility, resources and information should not be split up and given to several parties. An extra effort is also required on the part of the authorities to improve regulations and provide more vigilant supervision."

The AAIB report concluded that "in this case there was a clear connection between factors which did not individually cause the accident but which together led to catastrophe through mutual influence and the accumulated effect of this."

The report added: "The cause of the accident leads ... to the conclusion that documented traceability is of importance in establishing the airworthiness of aircraft parts."

The report said new European Joint Aviation Requirements address this issue and thus did not require further action on the AAIB's part.

In addition, the AAIB recommended that the Norwegian CAA change its current supervisory system "to improve its ability to deal with aircraft requiring special attention."

Although not all older aircraft require such attention, the report said, additional factors beyond age and operating hours, sometimes require extra vigilance. Those factors include aircraft that have been operated or maintained by several owners, aircraft subjected to extensive modifications and aircraft that have been in service in a corrosive environment.

Because the investigation revealed a history of vibration problems in the empennage on the type of aircraft involved in the accident (which was not well-known among all operators), the AAIB recommended that the CAA review the requirement for "new operators to obtain access to an aircraft's operations and maintenance history. This requirement should apply when primary acceptance inspections are being carried out."♦

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U.S. Aviation System Indicators Show No Decline in Safety

A task-force study developed 35 indicators to monitor the safety and efficiency of U.S. aviation. Current indicators are being refined and new indicators will be added in the FAA-developed system.

by
Russell Lawton
Aviation Consultant

The U.S. Federal Aviation Administration (FAA) in November 1993 released its most recent quarterly report of FAA-developed indicators that monitor the safety and efficiency of U.S. aviation.

The first quarterly report was issued in March 1993, the result of an FAA task-force study that developed indicators to reflect the status of the aviation system. The study was prompted by requests from the U.S. Senate Appropriations Committee, other U.S. government organizations and the aviation community.

The report, *Aviation System Indicators*, contains data for 35 safety, efficiency and environmental indicators that reflect current and past system performance. The data are classified as accident indicators, incident indicators, efficiency measures, compliance measures and inspector activity measures.

Accident/incident indicators include accident/incident rates for large air carriers, commuter air carriers, air taxis, general aviation, rotorcraft and midair collisions. Incident indicators also include rates of air carrier near midair collisions (NMACs), pilot deviations, operational errors and runway incursions. Also provided are the number of vehicle/pedestrian deviations.

The efficiency measures include facility/service reliability, facility/service operational availability, delay rates and delays due to volume rates. Compliance measures presently include the Stage III aircraft (noise abatement) ratio, and in the future will provide an airport certification indicator rate, airport certification system evaluation program and airworthiness indicator (aging aircraft).

A context for the system indicators is provided by environmental indicators, including measures such as the forecast of annual enplanements, the forecast of annual instrument flight rules (IFR) traffic handled at en route centers and the number of aircraft hours flown.

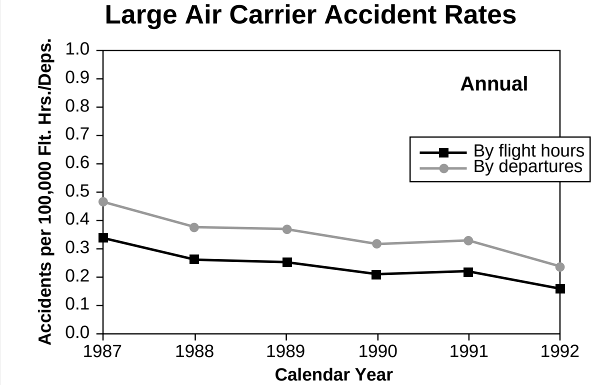
The report said, “With the exception of accident rates, it would be misleading to treat any one system indicator as an indicator of the status of the system." The report added: "Because of the many redundancies designed into the system to ensure a wide margin of safety, a change in one indicator does not by itself represent a change in overall system status. Movement of one indicator, however, can help FAA management and the aviation community focus resources to further investigate underlying factors, and thereby maintain and improve the wide margin of safety that the system is designed to provide."

No significant safety problems were cited in the report, which will be updated quarterly. Current indicators will be refined and new indicators will be added as part of an ongoing review process to assess the status of aviation system performance.

The following data from the report are accident indicators for large air carriers, commuter air carriers, air taxis and midair collision accident data as of Sept. 30, 1993.

Large Air Carrier Accidents

Figure 1 compares the number of accidents involving all large air carriers (i.e., operating under U.S. Federal Aviation Regulations [FAR] Parts 121, 125, or 127) to the number of flight hours and departures for these carriers for calendar years 1987 through 1992. This indicator is expressed as accidents per 100,000 flight hours and per 100,000 departures. Because most accidents occur during arrival or departure, the number of departures is considered to be the best normalizing variable. However, because departure data are not available for all operator types, rates based on flight hours are also calculated. The graph shows an overall downward trend during the six-year period for both rates per 100,000 flight hours and per 100,000 departures.



Source: U.S. Federal Aviation Administration, *Aviation System Indicators*

Figure 1

Table 1 (page 33) lists large air carrier accident data for calendar years 1987 through 1992 with a breakdown of the number of accidents, number of flight hours and the accident rate per 100,000 flight hours and per 100,000 departures. The accident rate per 100,000 flight hours decreased by 53 percent during the six-year period, while the number of hours flown increased by 14.89 percent. The accident rate per 100,000 departures decreased by 49 percent, while the number of departures increased by 5.1 percent.

The lower portion of Table 1 is a monthly listing of large air carrier accident data for the period October 1991 through August 1993. The monthly average accident rate per 100,000 flight hours ranged from a low of zero in December 1991 and June and September 1992 to a high of 0.49 in October 1991. The monthly average accident rate per 100,000 departures ranged from a low of zero in December 1991 and June and September 1992 to a high of 0.73 in October 1991. The 12-month moving average for August 1993 was up slightly for both flight hours and departures.

Figure 2 (page 34) shows large air carrier accident rates per 100,000 flight hours and per 100,000 departures by month with a 12-month moving average for October 1991 through August 1993. The monthly rate for both flight hours and departures dropped to zero in December 1991 and in June and September 1992. Both rates increased to more than twice the 12-month moving average in March and April 1993.

The 12-month moving average for accidents per 100,000 flight hours closely parallels the rate per 100,000 departures, showing a slight decrease in October 1992 and a slight increase by June 1993.

Commuter Air Carrier Accidents

The commuter air carrier accident indicator compares the number of accidents involving all commuter air carriers (i.e., scheduled carriers operating under FAR Part 135) to the number of flight hours and departures for these carriers. This indicator is expressed as accidents per 100,000 flight hours

Table 1
Large Air Carrier Accident Data

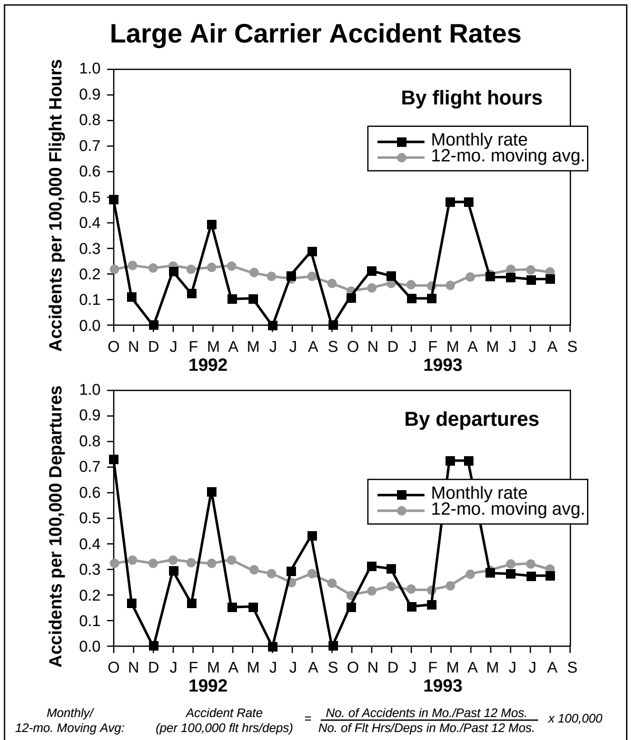
Calendar Year	Number of Accidents	Number of Flight Hours	Accident Rate (per 100,000 flight hours)		Number of Departures	Accident Rate (per 100,000 departures)	
1987	36	10,644,853	0.34		7,601,370	0.47	
1988	29	11,139,521	0.26		7,716,060	0.38	
1989	28	11,273,911	0.25		7,645,497	0.37	
1990	26	12,149,485	0.21		8,127,131	0.32	
1991	26	11,893,921	0.22		7,858,875	0.33	
1992	19	12,230,000	0.16		7,990,000	0.24	
Month			**Monthly**	**12-month Moving Average**		**Monthly**	**12-month Moving Average**
OCT 91	5	1,022,880	0.49	0.22	681,237	0.73	0.33
NOV 91	1	962,516	0.10	0.23	634,710	0.16	0.34
DEC 91	0	1,003,254	0.00	0.22	661,709	0.00	0.33
JAN 92	2	1,001,316	0.20	0.23	660,990	0.30	0.34
FEB 92	1	944,612	0.11	0.22	624,000	0.16	0.33
MAR 92	4	1,012,936	0.39	0.22	667,302	0.60	0.33
APR 92	1	988,651	0.10	0.23	654,793	0.15	0.34
MAY 92	1	1,002,694	0.10	0.20	663,629	0.15	0.30
JUN 92	0	1,024,996	0.00	0.19	668,121	0.00	0.29
JUL 92	2	1,074,963	0.19	0.17	698,652	0.29	0.25
AUG 92	3	1,077,079	0.28	0.19	699,646	0.43	0.29
SEP 92	0	1,017,560	0.00	0.16	664,057	0.00	0.25
OCT 92	1	1,034,699	0.10	0.13	676,477	0.15	0.20
NOV 92	2	991,660	0.20	0.14	636,724	0.31	0.21
DEC 92	2	1,058,834	0.19	0.16	675,609	0.30	0.24
JAN 93	1	1,050,578	0.10	0.15	686,355	0.15	0.22
FEB 93	1	981,948	0.10	0.15	641,518	0.16	0.22
MAR 93	5	1,061,137	0.47	0.15	693,253	0.72	0.24
APR 93	5	1,062,193	0.47	0.18	693,943	0.72	0.28
MAY 93	2	1,087,533	0.18	0.19	710,498	0.28	0.29
JUN 93	2	1,098,092	0.18	0.21	717,396	0.28	0.32
JUL 93	2	1,152,997	0.17	0.21	753,266	0.27	0.32
AUG 93	2	1,155,108	0.17	0.20	754,646	0.27	0.30
SEP 93		1,074,863			702,220		

Source: U.S. Federal Aviation Administration, *Aviation System Indicators*

and per 100,000 departures for calendar years 1987 through 1992. It shows a significant decrease from 1987 to 1988, a downward trend from 1988 to 1990, and an upward trend from 1990 to 1992 (Figure 3, page 34).

Figure 4 (page 34) shows commuter air carrier accident rates per 100,000 flight hours and per 100,000 departures by month with a 12-month moving average for October 1991 through August 1993. The 12-month moving average for accidents per 100,000 flight hours closely parallels the rate per 100,000 departures, showing a slight increase during 1992 and a slight decrease by August 1993.

Table 2 (page 35) lists commuter air carrier accident data for calendar years 1987 through 1992 with a breakdown of the number of accidents, number of flight hours and the accident rate per 100,000 flight hours and per 100,000 departures. The accident rate per 100,000 flight hours decreased between 1987 and 1990. The rate decreased by 44.5 percent from 1987 to 1988, with a 7.5 percent increase in hours flown. When compared to 1987 figures, the

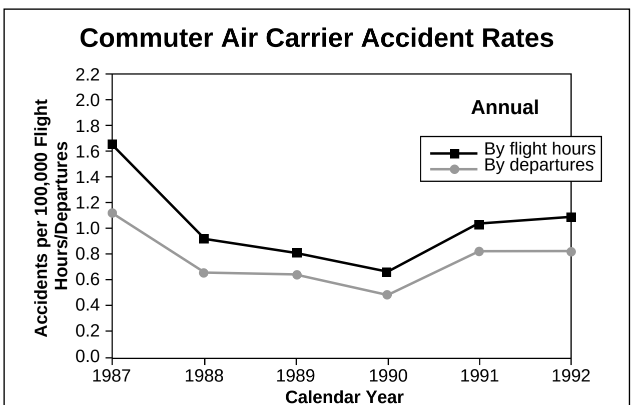


Source: U.S. Federal Aviation Administration, *Aviation System Indicators*

Figure 2

accident rate decreased by 60.9 percent in 1990, while the number of hours flown increased by 20 percent. The accident rate increased in 1991 and 1992 but, when compared to 1987 figures, the period ended with a 35.4 percent decrease while hours flown showed a 12 percent increase.

The accident rate per 100,000 departures also decreased between 1987 and 1990. The rate decreased by 42.98 percent in 1988, with a 3.5 percent increase in departures. When compared to 1987 figures, the accident rate decreased by 58.8 percent in 1990,



Source: U.S. Federal Aviation Administration, *Aviation System Indicators*

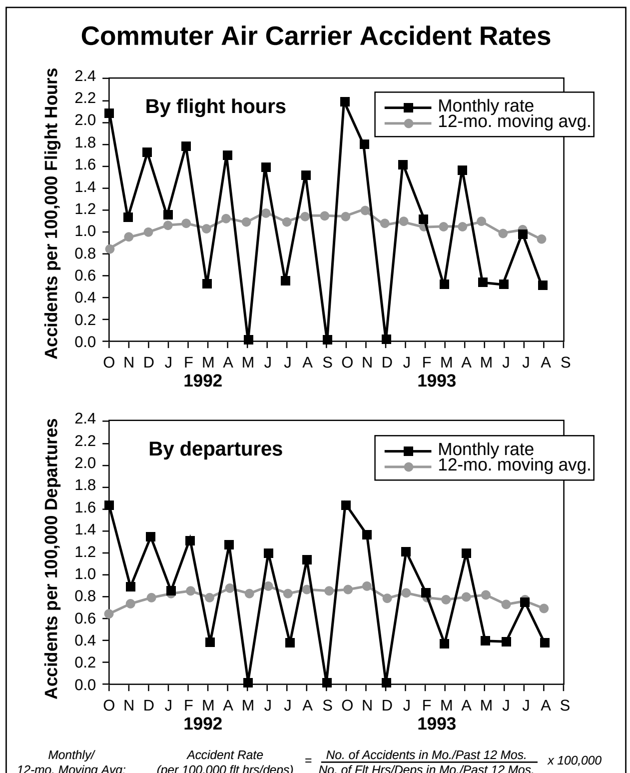
Figure 3

while the number of departures increased by 12.45 percent. The accident rate increased in 1991 and 1992 and, when compared to 1987 figures, ended the period with a 29.8 percent decrease while departures showed a 2.5 percent increase.

The lower portion of Table 2 lists complete commuter air carrier data for the period October 1991 through August 1993. The accident rate per 100,000 flight hours and per 100,000 departures is displayed by month and includes a 12-month moving average. The monthly average per 100,000 flight hours ranged from a low of zero in May, September and December 1992 to a high of 2.17 in October 1992. The monthly average per 100,000 departures ranged from a low of zero in May, September and December 1992 to a high of 1.66 in October 1991. The 12-month moving average for August 1993 was down slightly from July 1993 for both flight hours and departures.

Air Taxi Accidents

Table 3 (page 36) shows air taxi accident data for calendar years 1987 through 1992 with a



Source: U.S. Federal Aviation Administration, *Aviation System Indicators*

Figure 4

Table 2

Commuter Air Carrier Accident Data

Calendar Year	Number of Accidents	Number of Flight Hours	Accident Rate (per 100,000 flight hours)		Number of Departures	Accident Rate (per 100,000 departures)	
1987	32	1,946,349		1.64	2,809,918		1.14
1988	19	2,092,689		0.91	2,909,005		0.65
1989	18	2,240,555		0.80	2,818,520		0.64
1990	15	2,336,952		0.64	3,159,763		0.47
1991	22	2,171,602		1.01	2,718,720		0.81
1992	23	2,180,000		1.06	2,880,000		0.80
Month			**Monthly**	**12-month Moving Average**		**Monthly**	**12-month Moving Average**
OCT 91	4	192,312	2.08	0.87	240,764	1.66	0.69
NOV 91	2	176,127	1.14	0.96	220,501	0.91	0.76
DEC 91	3	174,223	1.72	1.01	218,117	1.38	0.81
JAN 92	2	173,291	1.15	1.06	228,935	0.87	0.84
FEB 92	3	168,959	1.78	1.09	223,211	1.34	0.87
MAR 92	1	190,620	0.52	1.04	251,828	0.40	0.82
APR 92	3	177,623	1.69	1.13	234,658	1.28	0.89
MAY 92	0	182,822	0.00	1.09	241,526	0.00	0.85
JUN 92	3	188,887	1.59	1.18	249,539	1.20	0.91
JUL 92	1	188,021	0.53	1.09	248,394	0.40	0.84
AUG 92	3	198,418	1.51	1.14	262,130	1.14	0.88
SEP 92	0	188,887	0.00	1.14	249,539	0.00	0.87
OCT 92	4	184,555	2.17	1.14	243,816	1.64	0.87
NOV 92	3	168,092	1.78	1.19	222,067	1.35	0.90
DEC 92	0	169,825	0.00	1.06	224,356	0.00	0.80
JAN 93	3	187,154	1.60	1.09	247,250	1.21	0.83
FEB 93	2	182,822	1.09	1.04	241,526	0.83	0.79
MAR 93	1	206,216	0.48	1.03	272,432	0.37	0.78
APR 93	3	192,353	1.56	1.03	254,118	1.18	0.78
MAY 93	1	197,552	0.51	1.07	260,986	0.38	0.81
JUN 93	1	204,483	0.49	0.97	270,143	0.37	0.73
JUL 93	2	207,083	0.97	1.01	273,577	0.73	0.76
AUG 93	1	212,281	0.47	0.91	280,445	0.36	0.69
SEP 93		203,617			268,998		

Source: U.S. Federal Aviation Administration, *Aviation System Indicators*

breakdown of the number of accidents, number of flight hours and the accident rate per 100,000 flight hours (Air taxis are defined as unscheduled carriers operating under FAR Part 135). When compared to 1987, the accident rate per 100,000 flight hours increased by 31.5 percent in 1990, while the number of hours flown decreased by 15.4 percent. The accident rate decreased in 1991 and 1992. When compared to 1987, the rate per 100,000 flight hours decreased by 8 percent and flight hours decreased by 16.1 percent by the end of 1992.

The lower portion of Table 3 shows complete air taxi accident data for the period October 1991 through August 1993. The accident rate per 100,000 flight hours is displayed by month and includes a 12-month moving average. The monthly accident rate ranges from a low of zero in October 1992 to a high of 5.50 in November 1991. The monthly accident rate for August 1993 was the highest it had been since November 1991, while the 12-month moving average for August 1993 was only slightly higher than for previous months.

Table 3 Air Taxi Accident Data				
Calendar Year	**Number of Accidents**	**Number of Flight Hours**	**Accident Rate (per 100,000 flight hours)**	
1987	97	2,657,000	3.65	
1988	101	2,632,000	3.84	
1989	111	3,020,000	3.68	
1990	108	2,249,000	4.80	
1991	88	2,241,000	3.93	
1992	75	2,230,000	3.36	
Month			**Monthly**	**12-month Moving Average**
OCT 91	4	195,648	2.04	3.85
NOV 91	10	181,870	5.50	4.06
DEC 91	5	179,115	2.79	3.93
JAN 92	7	169,285	4.14	3.84
FEB 92	7	165,378	4.23	3.93
MAR 92	2	186,213	1.07	3.48
APR 92	5	181,004	2.76	3.52
MAY 92	4	188,166	2.13	3.35
JUN 92	10	194,026	5.15	3.62
JUL 92	7	197,282	3.55	3.35
AUG 92	8	207,048	3.86	3.13
SEP 92	9	197,933	4.55	3.48
OCT 92	0	192,073	0.00	3.30
NOV 92	9	174,493	5.16	3.27
DEC 92	7	177,098	3.95	3.36
JAN 93	6	173,000	3.47	3.31
FEB 93	4	169,000	2.37	3.17
MAR 93	5	190,000	2.63	3.30
APR 93	5	185,000	2.70	3.30
MAY 93	8	192,000	4.17	3.47
JUN 93	7	198,000	3.54	3.33
JUL 93	5	201,000	2.49	3.23
AUG 93	11	211,000	5.21	3.36
SEP 93		202,000		

Source: U.S. Federal Aviation Administration, *Aviation System Indicators*

Figure 5 shows air taxi accident rates per 100,000 flight hours annually for calendar years 1987 through 1992, and by month with a 12-month moving average for October 1991 through August 1993. The annual accident rate per 100,000 flight hours increased in 1990, followed by a downward trend during 1991 and 1992.

Although the monthly accident rate showed some fluctuations, the 12-month moving average for accidents per 100,000 flight hours showed an even trend in 1993.

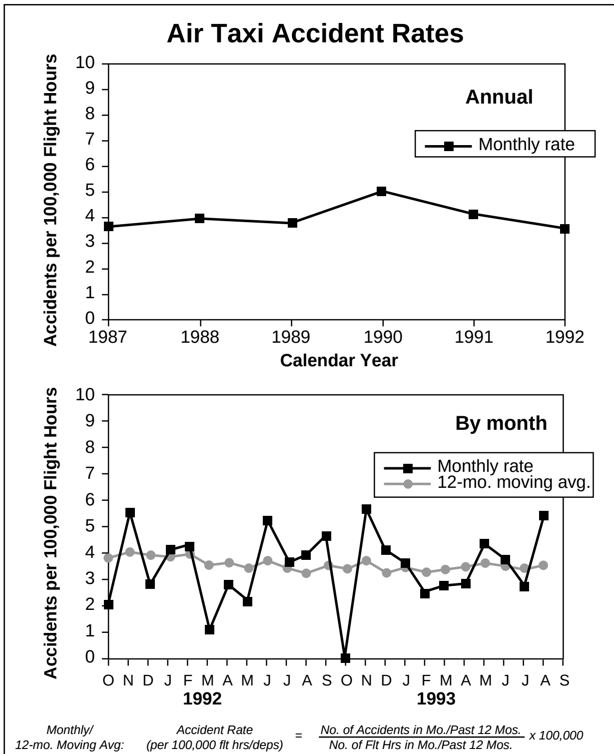
Midair Collisions

Table 4 (page 37) lists midair collision accident data for all operator types for calendar years 1987 through 1992, with a breakdown of the number of accidents, number of flight hours and the accident rate per 100,000 flight hours. When compared to 1987, the six-year period ended with a 49.15 percent decrease in the accident rate and a 3.67 percent increase in flight hours.

The lower portion of Table 4 lists by month complete midair collision accident data for the period October 1991 through June 1993. The accident rate per 100,000 flight hours is displayed by month and includes a 12-month moving average. The monthly accident rate decreased to zero in January and December 1992 and in January, May and June 1993.

The 12-month moving average ending June 1993 was slightly less than the 1992 yearly average.

Figure 6 (page 37) shows midair collision accident rates for all operator types per 100,000 flight hours annually for calendar years 1987 through 1992, and by month, using a 12-month moving average from



Source: U.S. Federal Aviation Administration, *Aviation System Indicators*

Figure 5

Table 4
Midair Collision Accident Data

Calendar Year	Number of Accidents	Number of Flight Hours	Accident Rate (per 100,000 flight hours)	
1987	25	42,220,202	0.059	
1988	19	43,310,210	0.044	
1989	18	44,454,466	0.040	
1990	22	45,245,437	0.049	
1991	21	43,532,524	0.048	
1992	13	43,830,000	0.030	
Month			**Monthly**	**12-month Moving Average**
OCT 91	1	3,833,911	0.026	0.041
NOV 91	2	3,362,396	0.059	0.046
DEC 91	2	3,153,236	0.063	0.048
JAN 92	0	3,203,275	0.000	0.048
FEB 92	1	3,267,470	0.031	0.046
MAR 92	1	3,703,389	0.027	0.046
APR 92	1	3,629,291	0.028	0.037
MAY 92	1	3,841,724	0.026	0.037
JUN 92	1	3,983,414	0.025	0.034
JUL 92	1	3,957,205	0.025	0.030
AUG 92	1	4,035,474	0.025	0.030
SEP 92	3	3,795,662	0.079	0.034
OCT 92	1	3,826,992	0.026	0.034
NOV 92	2	3,375,144	0.059	0.034
DEC 92	0	3,210,959	0.000	0.030
JAN 93	0	3,159,732	0.000	0.030
FEB 93	2	3,203,770	0.062	0.032
MAR 93	1	3,631,353	0.028	0.032
APR 93	1	3,582,546	0.028	0.032
MAY 93	0	3,805,085	0.000	0.030
JUN 93	0	3,919,575	0.000	0.028
JUL 93		3,908,080		
AUG 93		3,966,389		
SEP 93		3,728,480		

Source: U.D. Federal Aviation Administration, *Aviation System Indicators*

October 1991 through 1993. The annual accident rate per 100,000 flight hours decreased from 1987 to 1989, then increased slightly from 1989 to 1990, followed by a level-off in 1990 and 1991, and a downward trend from 1991 to 1992.

The monthly accident rate shows some wide fluctuations, from a low of zero in January and December 1992 and January, May and June 1993 to a high of 0.08 in September 1992. The 12-month moving average shows an overall decline for the period.♦

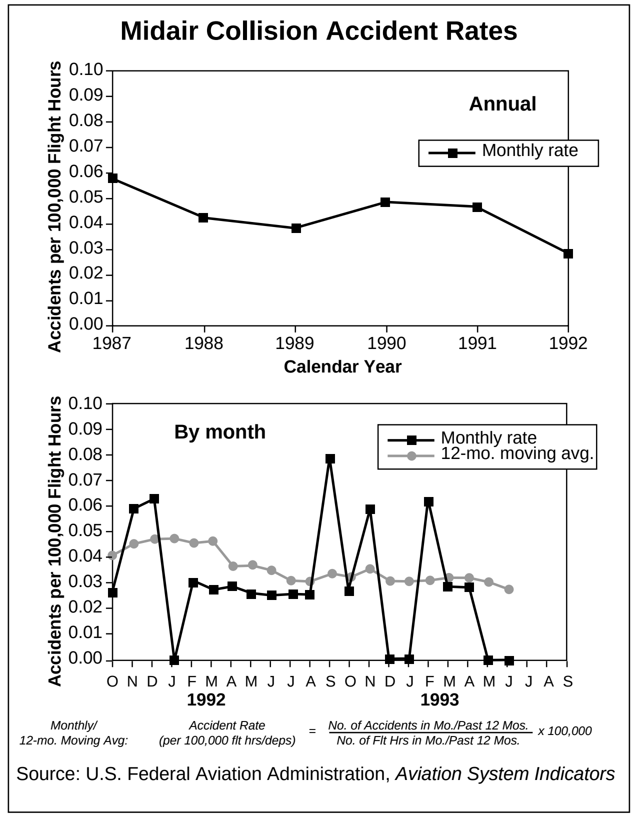


Figure 6

Editorial Note: This article was adapted from *Aviation System Indicators*, a special report prepared at the request of the U.S. Federal Aviation Administration, Office of Safety Information and Promotion, November 1993. Copies of the 87-page, illustrated report may be obtained by contacting the Associate Administrator for Aviation Safety, Office of Safety Information and Promotion, Federal Aviation Administration, 800 Independence Ave. S.W., Washington, D.C., 20591 U.S.

About the Author

Russell Lawton is an aviation safety consultant, a U.S. Federal Aviation Administration accident prevention counselor and editor of IFR Refresher *magazine.*

Lawton is the former vice president of operations for the Aircraft Owners and Pilots Association (AOPA) Air Safety Foundation, and served on the International Civil Aviation Organization (ICAO) Personnel Licensing and Training panel.

Lawton holds an airline transport pilot certificate, a flight instructor's certificate and has logged more than 5,000 flight hours.

Publications Received at FSF
Jerry Lederer Aviation Safety Library

Publications Highlight Human Factors — Physiological and Historical

One study looks at the relationship of stress-induced diminishment of human perceptional performance, while a recently published book explores the history of human factors research from its infancy to current topics of critical interest.

by
Editorial Staff

Reports

McLean, Garnet A.; Smith, Landgrave T.; Hill, Timothy J.; Rubenstein, Carl J. *Physiological Correlates of Stress-Induced Decrements in Human Perceptual Performance*, Report No. DOT/FAA/AM-93/19. A report prepared at the request of U.S. Federal Aviation Administration, Office of Aviation Medicine. November 1993. 14 p.; tables. Includes bibliographical references. Available through the National Technical Information Service.*

<u>Keywords</u>
1. Stress — Physiology.
2. Performance.
3. Sleep Deprivation.
4. Vigilance — Psychology.

Summary: Stress-induced changes in human performance have been thought to result from alterations in the "multidimensional arousal state" of the individual, as indexed by alterations in the physiological and psychological mechanisms controlling performance. Identifying such changes in underlying activities provides more complete descriptions of both the performance changes and the arousal state/mechanisms.

In this study, decrements in perceptual performance were produced by independent and combined administration of atropine (which causes dilation of the pupil), sleep loss and exercise for a visual aircraft identification task and an auditory vigilance task. Measurements of performance changes were accompanied by measures of cardiovascular function, pupillary diameter, sleep onset latency and subject self-reports.

Observed performance changes were accompanied by monotonic increase in heart rate after atropine and exercise, but not after sleep loss. Moderate exercise produced blood pressure changes indicative of physical workload, but only atropine increased diastolic blood pressure and pupillary diameter relative to performance effects. Atropine and sleep loss each reduced sleep onset times to less than 50 percent of control values. These reductions in general arousal were confirmed by subject self-reports of reduced attentiveness and competence. These measures of organismic function were found to be discriminatively correlative, but not predictive, of the decrements in perceptual performance seen. However, practical combinations of appropriate real-time measurement techniques could be developed that would promote the telemetering of human physiological activity to signal performance breakdown. [Summary]

Books

Wiener, Earl L.; Nagel, David C., editors. *Human Factors in Aviation*. San Diego, California, U.S.: Academic Press, 1988. 684 pp. ill. Includes index. ISBN 0-12-750031-6. Academic Press series in cognition and perception. Foreword by Jerome Lederer.

Keywords
1. Aeronautics — Human Factors.
2. Aviation.

Summary: By the standards of most areas of scientific endeavor, the field of human factors is still in its infancy. Most of the pioneers are alive today. The field was born during World War II, out of frustration that the machines of war were becoming so complex and demanding that they were outstripping the abilities of the military personnel to safely and effectively manage them. Most of the early work took place in aviation systems — aircrew equipment, training devices, instrument and cockpit design, and later radar. The book offers an introductory overview of the history and development of human factors research and then focuses on several areas critical to pilot performance and safety. Topics include human senses in flight, pilot workload, flight crew performance, human error, fatigue, pilot control, aircraft design, flight simulation, cockpit automation and air traffic control. [Preface]♦

*U.S. Department of Commerce
National Technical Information Service (NTIS)
Springfield, VA 22161 U.S.
Telephone: (703) 487-4780

Updated Reference Materials (Advisory Circulars, U.S. FAA)

AC Number	Month/Year	Subject
150/5200-28A	10/29/93	*Notices to Airmen (NOTAMS) for Airport Operators* (cancels AC 150-5200-2800, dated Oct. 1, 1987)

Federal Aviation Administration Orders

7110.10K CHG 1	11/10/93	*Flight Services* (This change transmits revised pages to order 7110.10K.)
7210.3K CHG 1	10/4/93	*Facility Operation and Administration* (This change transmits revised pages to order 7210.3K.)
7110.65H CHG 1	10/4/93	*Air Traffic Control* (This change transmits revised pages to order 7110.65H.)

Accident/Incident Briefs

Bilingual Exchange Causes Near-miss

DC-9 crew takes evasive action to avoid commuter aircraft.

by
Editorial Staff

The following information provides an awareness of problems through which such occurrences may be prevented in the future. Accident/incident briefs are based on preliminary information from government agencies, aviation organizations, press information and other sources. This information may not be entirely accurate.

Air Carrier

Bilingual Exchange Causes Near-miss

McDonnell Douglas DC-9. No damage. No injuries.

The DC-9 departed on an instrument flight rules (IFR) flight plan and was cleared southbound to 5,000 feet (1,525 meters).

The departure airport had no tower, but a flight service station (FSS) was in operation to relay advisories and direct visual flight rules (VFR) traffic.

No other IFR traffic was reported in the area at the time of the DC-9's departure. Later in the climb phase, FSS reported that a commuter aircraft had just canceled IFR and was inbound under VFR to land at the airport. As the DC-9 flight crew began to look for the commuter, they spotted it at 11 o'clock.

The DC-9 crew took evasive action and informed FSS in English of its actions. The crew of the commuter aircraft was communicating in French with FSS on the same frequency.

The DC-9 crew reported later that the commuter aircraft apparently never saw the DC-9, that the commuter crew was aware of the DC-9's departure and that the commuter's flight crew felt no concern because FSS was aware of both aircraft.

The crew of the DC-9 stated that the aircraft could not have passed any closer without sustaining damage.

Hasty Start Sends Ground Agent Scurrying

Boeing 767. No damage. No injuries.

After engine start, the flight crew completed the after-start checklist. The captain then asked the first officer to request permission to taxi.

Taxi clearance was issued. Because the aircraft had to depart the parking stand with a sharp right turn, more than usual power was applied. After a short delay, the aircraft began to move. A scraping noise was heard, and the captain immediately stopped the aircraft and set the parking brake.

It was determined later that the call “remove ground equipment, chocks, interphone, give clear sign left” for the ground technician had been forgotten. When the Boeing 767 began to move, it pushed the chock aside, and the technician fled the turning aircraft.

Prior to the departure flight, the captain had completed a long-range flight across six time zones. He had had 20 hours of rest following the 14-hour duty period. The captain suggested that the entry “ground equipment removed” be added to the after-start checklist.

Air Taxi Commuter

Check Flight Proves Fatal

Beechcraft C99. Aircraft destroyed. Two fatalities.

The C99 operated by GP Express Airlines crashed during a night proficiency flight.

After an investigation, the U.S. National Transportation Safety Board (NTSB) determined that the flying pilot (who was undergoing a six-month proficiency check) attempted to demonstrate a “prohibited aerobatic maneuver [a barrel roll at 1,000 feet (305 meters) above ground level AGL] to the check pilot, who voiced no objections.” [The U.S. Federal Aviation Administration (FAA) recommends that aerobatic maneuvers be completed at or above 3,000 feet (915 meters) AGL].

Both pilots were check airmen for the company and were friends, the NTSB said.

The NTSB said that the probable cause of the accident was the “deliberate disregard for U.S. Federal Aviation Regulations (FAR), GP Express procedures, and prudent concern for safety by the two pilots in their decision to execute an aerobatic maneuver during a scheduled check flight, and the failure of GP Express management to establish and maintain a commitment to instill professionalism in their pilots consistent with the highest levels of safety necessary for an airline operating scheduled passenger service.”

The NTSB recommended that the FAA require airlines operating under FAR Part 135 to “place personnel on duty with the ability to rapidly communicate with aircraft that are engaged in company-related flight activities when such activities are taking place, or require that an appropriate flight plan be filed for the operation.”

Rushed Approach Kills Eleven

Rockwell Turbo Commander 690. Aircraft destroyed. Eleven fatalities.

Fog at the destination forced the aircraft to divert under visual flight rules (VFR) to a nearby airport for a daylight landing.

The airport was in visual meteorological conditions, but there was fog over a nearby lake, which was on the final approach path.

On final, the aircraft entered instrument meteorological conditions (IMC), struck the water and sank. The two pilots and nine passengers were killed. The aircraft was recovered in 259.2 feet (79 meters) of water.

An investigation determined that the probable cause of the accident was the crew’s decision to continue a visual approach in IMC, poor interpretation of changing weather conditions and a lack of cockpit coordination.

Pressure to complete the flight aggravated by deteriorating weather conditions were contributing factors, investigators said.

Corporate Executive

Snow Bank Snares Propeller

Beech 200 King Air. Substantial damage. No injuries.

During a night landing, the aircraft touched down left of the runway centerline and the left propeller of the twin-engine aircraft struck a snow bank.

The aircraft veered off the left side of the runway and struck the snow bank again. Neither the pilot nor the six passengers on board were injured. Weather at the time was reported as light drizzle and fog.

Other General Aviation

Front Overtakes Twin On Cross-country Flight

Beech 55 Baron. Aircraft destroyed. Two fatalities.

The pilot was advised before departure of a weather front moving through the area of flight and of numerous flight precautions.

A short time later, about dusk, witnesses saw the aircraft flying at low altitude and circling in a mountain pass. Weather was reported as decreasing ceiling and visibility, high winds and rain mixed with snow.

Witnesses reported seeing the aircraft strike the ground in a nose-low, right wing-low attitude at high velocity. The pilot and a passenger were killed.

Very Short Final Destroys Lights

Piper PA23 Aztec. Substantial damage. Two serious injuries.

During the dusk approach, the pilot expressed some confusion when cleared for a right downwind to runway 08. Air traffic control (ATC) then amended the clearance for a left downwind for 08.

After establishing the approach, the pilot requested that the runway alignment indicator illumination be increased to assist him in identifying the correct runway. A few seconds later the aircraft collided with approach lights that were located 800 feet (244 meters), 600 feet (183 meters) and 400 feet (122 meters) from the runway threshold. The aircraft then struck an embankment and came to a stop about 300 feet (91.5 meters) from the runway. The pilot and a passenger were seriously injured.

Rotorcraft

Mountain Landing Goes Awry

Aerospatiale AS350B. Aircraft destroyed. No injuries.

The pilot was on short final to a mountain landing area when he decided to abort the landing. He then initiated a slow speed downwind turn.

During the turn, the helicopter encountered a down draft, and the pilot determined that the aircraft had insufficient performance to continue flight. An emergency landing was executed. On touchdown, the right skid struck a rock, and the helicopter rolled over. The four occupants escaped without injury but the helicopter was destroyed by a post-crash fire.

Safe Application of Technologies in Corporate Aviation

Flight Safety Foundation

39th Corporate Aviation Safety Seminar (CASS)

St. Louis, Missouri, U.S.
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For more information contact J. Edward Peery, FSF.

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