Volcanic Hazards and Aviation Safety: Lessons of the Past Decade

Avoiding the ash-laden cloud from a volcano is the only way to guarantee that an aircraft is not damaged by the cloud's dangerous particles, which can destroy an aircraft engine and threaten flight safety. Nature remains the ultimate force.

—

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Modern jet airplanes and their engines are designed to operate in environments that are free from dust and corrosive gases.

Explosive volcanic eruptions, such as the 1991 eruptions of Mount Pinatubo Volcano in the Philippines, inject large amounts of very small rock fragments, known as volcanic ash, and corrosive gases into the upper troposphere and lower stratosphere. Unfortunately, this is also the normal cruising altitude for jet airplane traffic.

Such explosive eruptions have occurred somewhere on earth about 10 times per year during the past decade.[6] Many of these explosive volcanoes occur around the Pacific "ring of fire" and have a direct impact on air routes around the Pacific basin. [The ring of fire refers to the chain of volcanoes located northward from Panama along the western coast of the United States, westward across the Aleutian Islands, southward along the various island chains bordering the Asian coast, through the islands in Malaysia and then eastward back into the Pacific Ocean.]

In the past 12 years, more than 60 modern jet airplanes, mostly jumbo jets, have been damaged by drifting clouds of volcanic ash that have contaminated air routes and airport facilities. Seven of these encounters are known to have caused in-flight loss of engine power to jumbo jets carrying a total of more than 2,000 passengers. The repair and replacement costs associated with airplane-ash cloud encounters are also high. The repair of the Boeing 747-400 damaged by an ash cloud from Redoubt Volcano, Alaska, U.S., in December 1989 was estimated to cost in excess of US$80 million.[12] Compounding the problem is the fact that volcanic ash clouds are not detectable by the present generation of radar instrumentation aboard aircraft. Complete avoidance of volcanic ash clouds is the only procedure that guarantees flight safety.

Ash Cloud Encounters In Early 1980s Spurred Study Of Safety Issues

The threat of volcanic hazards to aviation safety first received public attention when several commercial jet aircraft were damaged after flying through volcanic ash clouds from the

May 1980 eruptions of Mount St. Helens in Washington, U.S. Interest in the aviation safety issue grew rapidly in the early 1980s after several jumbo jets encountered ash clouds that had traveled several hundred miles from their sources. Eruptions of Galunggung Volcano in Indonesia in 1982, Redoubt Volcano in Alaska, U.S., in 1989 and 1990, and Mount Pinatubo Volcano in 1991 caused significant damage to aircraft, including engine failures, and severely disrupted regional air operations. Ash clouds from eruptions in Colombia, Italy, Japan, the United States and Zaire have also damaged aircraft.

Ash Clouds Vary in Type and Severity

Active volcanoes emit several types of plumes and clouds. Quiescent plumes consist of water vapor and gases with few or no rock particles. They seldom rise above 20,000 feet (6,060 meters) and usually disperse within tens of miles of the volcano. Quiescent plumes are not a significant threat to aviation safety.

Eruption columns are the violent, cauliflower-shaped pillars of ash and gas generated above a volcanic vent during an explosive eruption. Within tens of minutes some columns can rise to altitudes of 40,000 feet (12,121 meters) to 100,000 feet (30,303 meters). They typically contain blocks of volcanic rock up to several inches in diameter, plus dense concentrations of ash and gas. Eruption columns seldom last for more than a few hours and only affect an area within a few miles of the volcanic vent, so they pose a relatively small threat to aviation safety. However, because eruption columns contain large blocks of rock, they must be avoided by aircraft.

Drifting ash clouds pose the greatest threat to aircraft.

Drifting ash clouds consist of finely broken rock fragments and gas that are carried away by winds from a violent eruption column. Large volcanic eruptions produce clouds that enter the stratosphere and may be carried by the jetstream for thousands of miles. Although these ash clouds can circle the globe in a matter of weeks, they usually deposit most of their ash within a few hours to a few days. Drifting ash clouds pose the greatest threat to aircraft.

Mitigating the ash hazard is complex because ash clouds are difficult to detect by conventional weather radar or visually from an airplane. Ash clouds are very difficult to detect at night, and they may be obscured by weather clouds. Ash clouds must be tracked by relying on volcanological observers on the ground, pilot reports (PIREPS), satellite observations and meteorological forecasts of ash-cloud movements. Immediate communication from ground observers and meteorologists to aircraft dispatchers and controllers, and to pilots, is essential.

Three Eruptions Affected Aircraft Operations Significantly

Three eruptions of the past decade have greatly helped to focus attention on the problem of volcanic hazards and aviation safety. Each of these eruptions included multiple encounters between aircraft and drifting volcanic ash clouds.

In 1982, two Boeing 747-200 passenger jets encountered ash at night from separate eruptions of Galunggung Volcano in Java, Indonesia.[11] In each case, pilots observed St. Elmo's fire, noted the acrid smell of sulfur gas, observed fine dust quickly filling the cabin and experienced moderate turbulence while in the ash cloud.[14] In both cases, volcanic ash entered the jets' engines and caused surging, flameout and immediate thrust loss of all four engines. After powerless descents of nearly 25,000 feet, the pilots of both aircraft eventually restarted all engines and landed safely at Jakarta. Both aircraft suffered extensive damage to engines and exterior surfaces.

The December 1989 to April 1990 eruption period of Redoubt Volcano widely affected commercial and military airplane operations near Anchorage.[4] These affects included rerouting and cancellation of flight operations for some time, which significantly affected the Anchorage economy.

From December through February, ash clouds from Redoubt damaged five commercial jet liners. The most serious incident occurred on December 15, 1989, when a new Boeing 747-400 encountered a drifting ash cloud while descending to land at Anchorage. On entering the cloud at 25,000 feet (7,576 meters), about 150 miles (242 kilometers) northeast of Redoubt, the pilot tried to fly out of the ash cloud and had climbed nearly 3,000 feet (909 meters) before all four engines failed. The aircraft descended 13,000 feet (3,939 meters) without power before the engines were restarted and flight resumed to Anchorage. No passengers were injured, but the aircraft's engines, avionics and exterior were damaged extensively. Repair costs were estimated to exceed $80 million.[12]

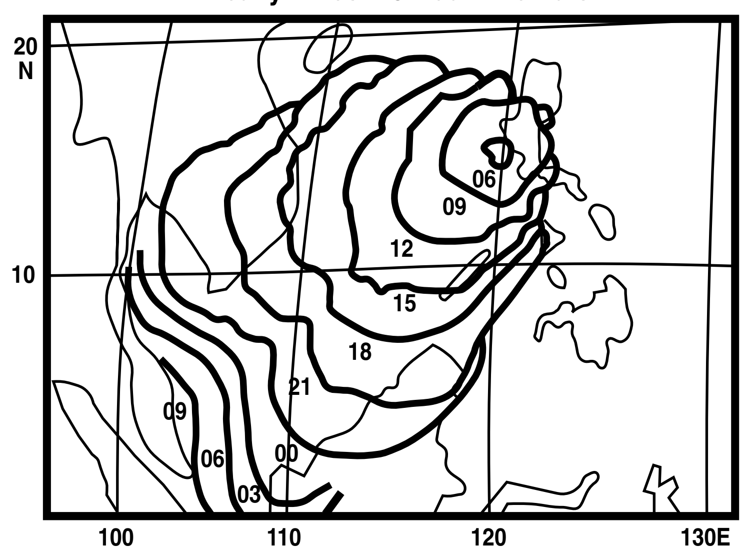
Other damaging encounters between jet aircraft and ash clouds from Redoubt were reported on December 15 and 16, 1989, and February 21, 1990. Fortunately, these aircraft did not experience engine failures. Following the eruptions and encounters on December 15 and 16, Anchorage International Airport remained open. Most air carriers, however, canceled operations for up to several days, and some international carriers canceled or curtailed operations through January 1990. These curtailments reduced revenues at Anchorage International Airport by approximately $2.6 million.[3]

The June 15, 1991, eruption of Mount Pinatubo was the largest of the past 60 years.[7] The eruption produced a huge ash cloud that moved rapidly to the west over the South China Sea, Borneo and Indochina Peninsula (Figure 1), disrupting aircraft operations over a broad area of the Philippines and Southeast Asia. Five airports in the Philippines, including Manila International Airport and military airfields at Basa, Clark, Sangley and Cubi Point, were damaged by ashfall, which occurred during a major typhoon and covered airfields at Basa, Clark and Cubi Point with up to six inches of ash. The wet ash and constant ground shaking on June 15 led to the collapse of numerous aircraft hangars and maintenance facilities at several airfields. Manila International Airport was closed from June 15 to 19 and did not resume normal operations until July 4. Clark and Basa remain closed.

At least 20 commercial jet airplanes were damaged by volcanic ash. Most damage was because of in-flight encounters with ash clouds from Pinatubo. These in-flight encounters involved 10 Boeing 747s, five DC-10s, one L-1011, and one Boeing 737. Because of ash ingestion, a total of 10 engines, including four engines on a single Boeing 747, were badly damaged and had to be replaced. Several other airplanes were damaged on the ground by ash loading and improper removal of ash from cockpit windows.

Development of the Pinatubo Ash Cloud, June 15-16, 1991

Heavy Lines = 3-hour Intervals



Source: Tanaka and Hamada, 1991[13]

Figure 1

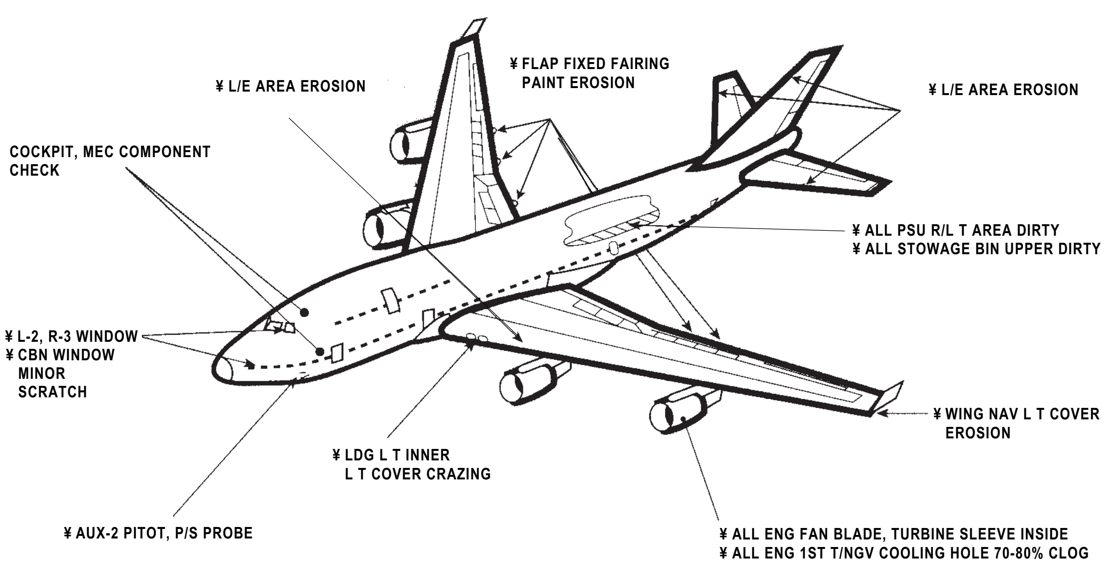
Unlike encounters at Galunggung and Redoubt, which caused multiple engine failures and occurred within 150 miles (242 kilometers) of the erupting volcano, the majority of Pinatubo encounters were at distances of more than 600 miles (967 kilometers) from Pinatubo. Only two encounters occurred during landing approaches to Manila. All other encounters were to the west in the Singapore, Ho Chi Minh and Hong Kong Flight Information Regions. This large number of encounters reflected a major breakdown in the ways that information about the ash-cloud hazard was communicated. In the Philippines, volcanologists of the Pinatubo Volcano Observatory were aware of the eruptions at the time they occurred. With access to real-time satellite information, meteorologists and volcanologists in the United States were also aware of the volcano's activity, including the speed and direction of the ash cloud's movement. The key problem was one of timely communication of this information to the proper agencies in the aviation community.

Aircraft Damage Can be Immediate and Long-term

A range of damage may occur to an airplane that has flown through a volcanic ash cloud (Figure 2). Effects may be apparent immediately or they may take longer to manifest themselves. Immediate effects are easy to identify and, in some cases, easily repaired. Medium-term and long-term effects are considerably more difficult to identify and are primarily related to the gaseous components in the volcanic cloud, especially the acid gas sulfur dioxide.

When a modern jet aircraft, traveling at high speed, encounters a drifting cloud of sand-size rock fragments, a wide variety of damage will occur and the consequences are usually evident immediately. Volcanic ash is typically composed of a mixture of sharp, angular fragments of rapidly quenched volcanic glass, as well as mineral and rock fragments that range in size from fine powder to fragments up to an eighth of an inch in diameter. Fragments typically include the minerals feldspar, quartz and pyroxene. The ash is hard and can easily scratch and abrade glass, plastic and metals. Any forward-facing surface of the airplane, such as windows, landing light covers, leading edges of the wings and the fuselage, will be damaged (Figure 2). Because of its small size, ash also can enter very small openings in the aircraft exterior, including the air supplies for flight instruments such as the pitot static system.

The ingestion of volcanic ash by jet engines may cause serious deterioration of engine performance or even engine failure (Figure 3). Since 1980, at



Source: Thomas J. Casadevall

Diagram of Boeing 747-400 Aircraft Showing Exterior Damage from Ash Cloud

Figure 2

least seven encounters between jet-powered aircraft and volcanic ash clouds have resulted in temporary engine failures. Two processes deteriorate engine performance: erosion of moving engine parts, such as compressor and turbine blades, and accumulation of partially melted ash in hot zones in the engine. Erosion of compressor blades reduces the compression efficiency of the engine but has not been proven to cause engine failure. Ash deposits in the hot sections of the engines, including the fuel nozzles, the combustor and the turbine, reduce the efficiency of fuel mixing and restrict air passing through the engine. This causes surging, flameout and immediate loss of engine thrust. This loss is the principal cause of engine failure.

Air that enters the airplane cabin is taken from the engine. This air powers generators and pneumatic systems throughout the aircraft and provides breathing air for passengers. The air passes through an environmental control system and is carried through ducts to appropriate parts of the aircraft.

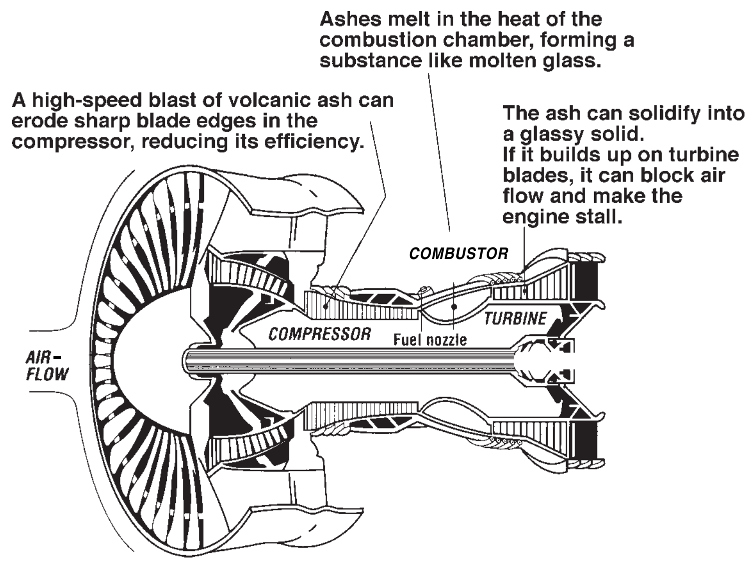
Ash particles may abrade completely through the duct system as well as clog filter systems designed to remove moisture from the air.

Flying an airplane through an ash cloud causes damage that is immediately evident. More difficult to evaluate is the damage that occurs by repeated long-term exposure to the clouds of mostly gas and gas-derived particles that remain in the stratosphere. For large eruptions, such as Mexico's El Chichon in 1982, and Pinatubo in 1991, these gases may remain suspended in the stratosphere for years after the solid rock particles have settled. The sulfur dioxide in the clouds absorbs water vapor and is converted to droplets of sulfuric acid. When aircraft fly in a stratosphere polluted with volcanic aerosols, these acid droplets adhere to aircraft skins and windows and may penetrate microcracks in those surfaces. This is most easily observed in acrylic windows where the clouding and crazing of acid-attacked windows prompts their replacement.[8,9,1]

Other corrosion damage to plastics and rubber used in seals and lubricants and metal components used in the airframe is not as easily identified. Identifying corrosion damage to these components may require long-term programs of inspection and maintenance. Even then, corrosion by volcanic pollution may be impossible to distinguish from other environmental pollution such as salt in sea spray and acid gases in polluted urban atmosphere.

Because engines are typically inspected and rebuilt more frequently than the rest of the airplane, the problems of engine corrosion by volcanic gas may be more easily identified and addressed during regular maintenance.

Jet Engine Cutaway Showing Areas of Damage by Ash Cloud



Source: Thomas J. Casadevall

Figure 3

Nevertheless, the airframe and skin are most susceptible to long-term influence from repeated exposure to volcanic clouds. Scientists and engineers have not yet assessed the long-term effect of corrosion by acid components in volcanic clouds.

Aircraft Also Face On-ground Ash Hazards

It is easy to appreciate the nature of damage that occurs during an in-flight encounter with an ash cloud. However, a host of additional problems face an airplane sitting or taxiing on the ground. For example, ashfall of more than several inches will place a considerable load on an aircraft, especially if the ash falls wet with rain. Some aircraft may respond to loading by settling back on their tail sections. Ash loading also may cause hangars to collapse, especially if ash falls wet and if ground shaking caused by volcanic earthquakes is strong and prolonged, as it was during the Pinatubo eruption.

Ash covering airport runways and taxiways is easily resuspended for days to weeks by wind and by ground movement of aircraft for takeoffs, landings and taxiing. Ingestion of resuspended ash by jet engines, especially during full-power takeoff, may be just as damaging as ash encountered while in flight. When wet, ash becomes slippery because of its fine grain size. Slippery ash reduces the coefficient of friction between tires and the runway surface, thus affecting the braking and turning performance of aircraft.

Avoiding an ash cloud is the only way to guarantee that an aircraft is not damaged.

Removing ash from an airplane and its engines must be done with care. Simply washing fine ash from an airplane's exterior must be avoided because water added to ash produces a slurry that may penetrate openings in the skin surface. Subsequent removal is costly and may require disassembling the airplane. A simple three-step procedure is recommended for removing ash from the surface of an airplane parked on the ground: (1) sweep ash away with a broom; (2) vacuum remaining ash with an industrial vacuum; and (3) wash away remaining fine ash, being careful to wash away from openings in the airplane surface.

Only a few airports have had to deal with volcanic ashfall. One facility where carriers and managers have experience is Kagoshima Airport in Japan, which receives frequent ashfall from nearby Sakurajima Volcano. While there are some common elements in the cleanup efforts at each airport, airport managers and ground crews have typically relied on local solutions for their cleanup efforts. The type of cleanup effort will usually depend on the amount of ashfall.

Ashfalls less than 0.25 inch (6.2 millimeters) can usually be handled by thoroughly washing airport surfaces, if adequate water and drainage capacity is available. For thicker ashfalls, initial washing is discouraged because ash is likely to fill and block drainage lines. Instead, experience shows that accumulating the ash into mounds large enough to remove with earthmoving equipment is the best first step. This may be followed by washing. If ash is moved to the edges of runways and taxiways, it should be removed or stabilized with quick-growing grass or emulsified asphalt to avoid resuspension of ash by aircraft movement or wind. This method was used successfully at Manila International Airport and Cubi Point Naval Air Station after the 1991 eruptions of Pinatubo.

Research and Experience Have Yielded Valuable Lessons

At considerable expense during the past decade, some important lessons have been learned about the threats that volcanic ash poses to aviation safety in the air or on the ground. An aircraft cannot fly through an ash cloud without sustaining some damage. Avoiding an ash cloud is the only way to guarantee that an aircraft is not damaged.

As existing instruments aboard aircraft simply cannot detect or locate an ash cloud, the most important lesson is that immediate communication to a pilot about a potential volcanic threat is essential to successful avoidance. Three essential sources of information about volcanic activity and ash clouds include observations from ground-based observers to alert and verify an eruption; from pilots, through pilot reports about eruptive activity and ash clouds; and from satellite observations to detect and track ash clouds.

No single source of information is completely reliable and feedback between these three sources is essential for complete and accurate communication. National and international organizations have initiated efforts to improve communications between volcanologists, meteorologists, air traffic controllers and pilots. Yet, the improvements cannot substitute for increased pilot awareness about what to do when an ash cloud is entered inadvertently.

Aircraft must avoid flying into volcanic ash clouds. Avoiding an ash cloud may be difficult or even impossible for an airplane in flight, especially at night. Although such an encounter will almost surely result in some damage to the airplane, depending on the ash content of the cloud and the duration of the encounter, the aircrew can minimize the damage by reducing engine power and reversing course to escape the ash cloud. Such actions require that pilots be well informed about the nature of ash clouds and that they be trained in procedures to minimize damage.

If the aircraft experiences engine failure, pilots must be aware that engine parameters such as temperature and turbine speed for engine starts at high altitude differ from normal starts made on the ground.

If the aircraft experiences engine failure, pilots must be aware that engine parameters such as temperature and turbine speed for engine starts at high altitude differ from normal starts made on the ground. Analysis of incidents where engines failed because of ash ingestion indicates that in some cases initial restart attempts would probably have been adequate had pilots been aware of the characteristics of high-altitude engine restarts.

For aircraft on the ground or en route toward a potentially hazardous ash cloud, communications between controllers, dispatchers and pilots can usually lead to successful avoidance. This will typically mean carrying additional fuel or planning alternate routes to avoid the contaminated airspace.

The United States has 56 volcanoes that have erupted during the past 200 years. Forty-four of these volcanoes are located in Alaska, including 30 in the 1,000-mile-long (1,613 kilometers) Aleutian Island chain. The U.S. Geological Survey (USGS) is responsible for assessing volcanic hazards and monitoring restless volcanoes in the United States.[15] Only 19 of the 56 U.S. volcanoes are monitored by the USGS from volcano observatories located in Hawaii, Washington and Alaska. Presently, only one of the 30 historically active Aleutian Island volcanoes is monitored. This gap in monitoring coverage is especially critical in view of the large number of commercial and military aircraft that use the great circle routes.

While the USGS efforts focus on ground-based studies, the U.S. National Oceanic and Atmospheric Administration (NOAA) and the U.S. Federal Aviation Administration (FAA) monitor and track volcanic ash clouds in the United States with satellite imagery and pilot reports. In 1989, NOAA and the FAA initiated a joint effort to track volcanic ash clouds and to warn pilots via notices to airmen (NOTAMs). Based on experience gained from the 1989 to 1990 Redoubt eruptions and the 1991 Pinatubo eruption, the NOAA-FAA effort will also formally link the USGS into the process of informing pilots about the threat of volcanic ash clouds.

In cooperation with the International Civil Aviation Organization (ICAO) and the Air Line Pilots Association (ALPA), the USGS continues to seek ways to inform and educate the aviation community about volcanic hazards and what steps can be taken to mitigate and minimize an ash-airplane encounter — in the air and on the ground — in ways that promote the safety of air travel.

The growing number of ash encounters during the past decade has prompted several international efforts to evaluate and address the problem of volcanic hazards to aviation safety. In 1982, a Volcanic Ash Warnings group was organized under leadership of ICAO. Also in 1982, the Australian Department of Aviation created an Airways Volcano Watch.

A May 1985 encounter between a Boeing 747-200 and an ash cloud from Soputan Volcano in Sulawesi, Indonesia, prompted the Indonesian and Australian governments to form a liaison committee to improve communications about volcanic eruptions in the Indonesian region.

In 1988, ICAO member states adopted amendments for an International Airways Volcano Watch to provide alerts about eruptive activity worldwide. These efforts included development of a special form for pilots to report volcanic events.[5]

Communicating past experiences and practical solutions to pilots and the airlines is key to solving the ash-aircraft problem. The efforts of a wide variety of agencies, both public and private, led to the First International Symposium on Volcanic Ash and Aviation Safety, held in Seattle, Washington, U.S., in July 1991.[4] The symposium sought to encourage improvements in the detection, tracking and warning of volcanic ash hazard so that aircraft may avoid ash clouds; and to review the effects of volcanic ash on aircraft so that pilots who encounter ash might respond appropriately. More than 200 participants from 23 countries attended the symposium.

The manufacturers' principal trade association, the Aerospace Industries Association of America (AIAA), formed a Volcanic Ash Study Committee in February 1991 and presented its recommendations at the international symposium. In connection with the Seattle symposium, ALPA, the Air Transport Association of America (ATA) and the Flight Safety Foundation have actively communicated about the volcanic ash problem to their members and constituents, both nationally and internationally.

Volcanic Ash Threat Will Remain in Coming Years

During the past decade, we have learned some hard lessons about the threat that volcanic ash presents to the modern jet airplane and its engines. This threat is not likely to disappear in coming years. The best solution to the problem is to avoid areas contaminated by ash. Avoidance requires the coordinated efforts of a broad group of technical specialists including volcanologists, meteorologists, dispatchers, pilots and controllers, all working together to detect and track volcanic ash clouds and to provide warnings about volcanic hazards to aviation safety. The goal of these efforts is to avoid an area or airspace that has been contaminated by volcanic ash and corrosive volcanic gas.

Changes to the technical design of airplanes and powerplants have been considered and rejected as being too costly or impractical. Development, particularly in Australia, of sensors carried on the airplane is in the early stages and is a future hope to assist pilots to avoid ash clouds, especially for air routes over remote regions where volcanoes are largely unmonitored.

Because ash clouds often drift over national boundaries and between flight information regions, regional air traffic facilities and carriers must be informed about potential volcanic threats, not just in their local flight region, but in adjacent regions as well. The hazards posed by volcanic clouds have a global scope that requires both local and global approaches to ensure a successful solution. ♦

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About the Author

Thomas J. Casadevall is the project chief for Volcanic Hazards and Aviation Safety at the U.S. Geological Survey (USGS). He coordinates USGS activities with other federal agencies and with nongovernmental groups in the area of aviation safety. He has worked with the USGS Volcano Hazards Program since l978 and has been a member of numerous research teams working at active volcano sites around the world. He holds an M.A. in geology and a Ph.D. in geochemistry.

FSF-urged Communication Link Allowed Warning of Volcanic Eruption

The eruption of the 10,560-feet (3200-meters) high Mt. Shivelutch Volcano on the Kamchatka Peninsula, on April 17, 1993, is only one of the most recent volcanic eruptions that underscored the importance of the international seminar "Volcanic Activity and Problems Related to Aviation Safety," conducted Sept. 8-12, 1992, on the Siberian peninsula of Kamchatka in the Russian Far East. [*Flight Safety Foundation News,* October/November/December 1992, "Volcanic Hazards to Flight Highlight Russian Conference, Signals Further Opening of CIS"].

One important outcome of the seminar was that Flight Safety Foundation-Commonwealth of Independent States (CIS) communicated FSF's recommendation by John H. Enders, FSF vice chairman, to the CIS Minister of Communications that a direct communications link be established between the Kamchatka Region and the West. A telephone link to Japan was established after FSF's recommendation, but that link is still subject to various problems in the Russian telephone system.

The timely warning of the Mt. Shivelutch eruption was the first time, for instance, that Japanese aviation authorities had received notice directly from the authorities in the Kamchatka Region of a volcanic eruption, a fairly frequent geological event in that part of the world. This measurable improvement in communications between CIS-volcanologists and the worldwide aviation community is a direct result of the seminar.

Nevertheless, goodwill, such as that shown by the personnel involved in this timely warning, cannot be a long-term substitute for a routine, reliable and timely communications system. More work must be done to improve the speed and accuracy of information about volcanic eruptions that may create hazardous conditions for aviation operations across the northern Pacific Ocean and along newly opened routes across Siberia and the Russian Far East.

FSF and FSF-CIS sponsored the seminar in cooperation with the Kamchatka Regional Administration, Far East Institute of Volcanology, Aeronautical Meteorological Observation Office of Petropavlovsk-Kamchatskii, KamchatAvia Airlines, Kamtchatka Joint Aviation Group and Alpha Tours. The 60 seminar participants, including volcanologists, geologists and other scientists, and aviation representatives from flight operations, air traffic control and meteorology, reached several important conclusions during the seminar discussions, including the following:

1. The Kamchatka Region produces a wide spectrum of volcanic activity, some of which constitute hazards to safe aircraft flight;

2. The region's volcanic observation-station network appears to be adequate for scientific purposes, but additional resources could improve its effectiveness in alerting the aviation community of volcanic activity, which would allow for rerouting of flights to avoid hazards;

3. The region's scientists are competent and highly trained; and,

4. The region's communications network is the weak link in warning the aviation community of volcanic hazards.

The seminar served its purpose in presenting the actual state of volcanic activity (especially in the CIS) and its relation to aviation safety. The results of the seminar's discussions, which were presented the following week to the International Civil Aviation Organization's (ICAO) "Volcanic Ash Hazards" meeting in Bangkok, Thailand, added up-to-date information to the ICAO meeting.

FSF and FSF-CIS are considering future meetings in Kamchatka that will augment and complement volcano-related activities by ICAO and the U.S. Federal Aviation Administration (FAA).♦

Aviation Statistics

Canada Surveys Pilots in Small Commercial Operations

by

Transportation Safety Board of Canada

In 1990, more than 90 percent of the 229 accidents involving Canadian aircraft commercial operations occurred to Level III through Level VI operators — small commercial operations (Figure 1). Their accident rate is estimated to be nine per 100,000 hours, compared to 0 and 1.2 for Levels I and II (large air carriers), respectively.

Without reliable reference data regarding the current operating practices of small commercial operations, aviation safety investigators are frequently unable to determine whether a problem discovered during the course of an accident investigation is specific to that accident or is applicable to all operations of that type, and warrants broader safety action. Therefore, a national survey was undertaken to obtain operational, social, economic and psychological information about pilots employed in small commercial operations and to assist in the evaluation of operating practices in the light of the recent Canadian accident record.

Four Thousand Pilots Surveyed

Survey questionnaires were sent to professional pilots; the target group was estimated to be about 4,000 individuals. By the end of March 1991, 2,023 responses had been received from pilots employed by large and small air carriers; 954 of them had worked for small air carriers in the preceding 12 months but were unemployed at the time of the survey. Fixed-wing and rotary-wing pilots' questionnaire files were processed and cross-tabulated together in a first stage, and then independently to identify any significant differences between the two types of flying.

Pilots Are Young

The pilot population of small air carriers is young; 70 percent of the respondents were less than 40 years of age and 35 percent less than 30 years of age. Only 6 percent were more than 54 years of age. There was a lower percentage (16 percent) of rotary-wing pilots less than 30 years of age.

Most respondents (96 percent) were male; 54 percent were married; and 46 percent were

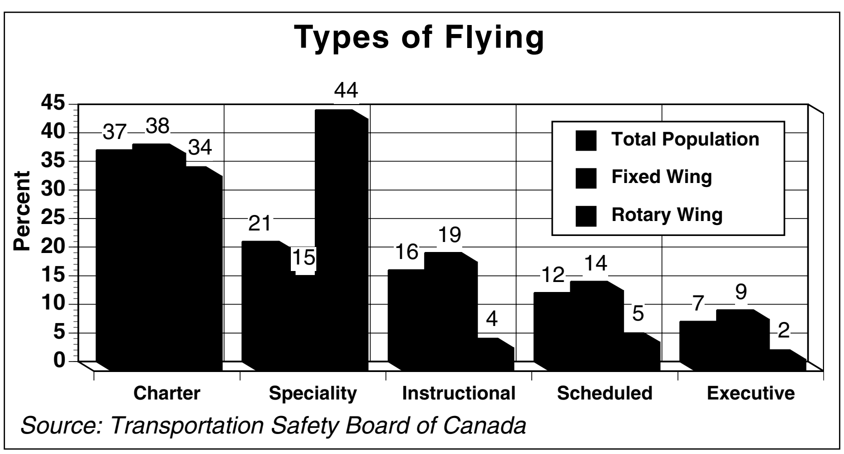

Figure 1

either single, separated, divorced or widowed.

Pilots' Backgrounds Vary

Low-time (less than 2,500 flight hours) fixed-wing pilots were proportionately in larger numbers than low-time rotary-wing pilots. At the upper end of the scale, high-time rotary-wing pilots were proportionately more numerous than their fixed-wing aircraft colleagues (Figure 2).

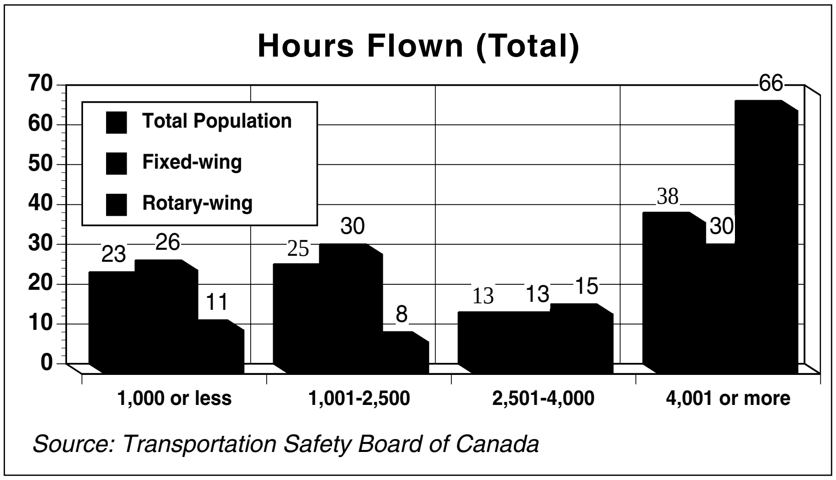

Figure 2

This overall greater flying experience amongrotary-wing pilots is also matched by a greater number of years of experience. It is also observed that, globally, about 40 percent of the pilots had less than four years of experience and 40 percent had more than nine years. The fact that less than 20 percent of thepilots have four to nine years of experience suggests that pilots either continue working past nine years as pilots for small air carriers or quit before having flown for four years.

In the previous 12 months, 14 percent of the respondents had experienced an aviation occurrence (accident or incident). In 81 percent of the cases, the respondent was pilot-in-command.

Rotary-wing Pilots Paid More

Approximately half of the air carriers that employed the respondents hired 10 pilots or fewer. Rotary-wing operators employing 25 pilots or more were reported in significantly larger proportion (43 percent) than their fixed-wing counterparts (21 percent). Two-thirds of the rotary-wing pilots were employed by operators who had fleets of 11 aircraft or more. More than a third of the respondents were employed by air carriers that operated five aircraft or less.

Rotary-wing pilots (68 percent) had full-time work contracts more frequently than fixed-wing pilots (56 percent). Almost two-thirds (65 percent) of the respondents were employed year-round. The most commonly reported modes of remuneration were: fixed annual salary (29 percent); fixed daily, weekly or monthly salary (28 percent); basic salary plus premium for each hour flown or mile completed (25 percent); and hourly salary (20 percent). The average (median) income of the respondents when they obtained revenue solely from flying was between C$15,000 and $29,999. Fifty-five percent of the rotary-wing pilots earned more than $40,000; this was true for only 20

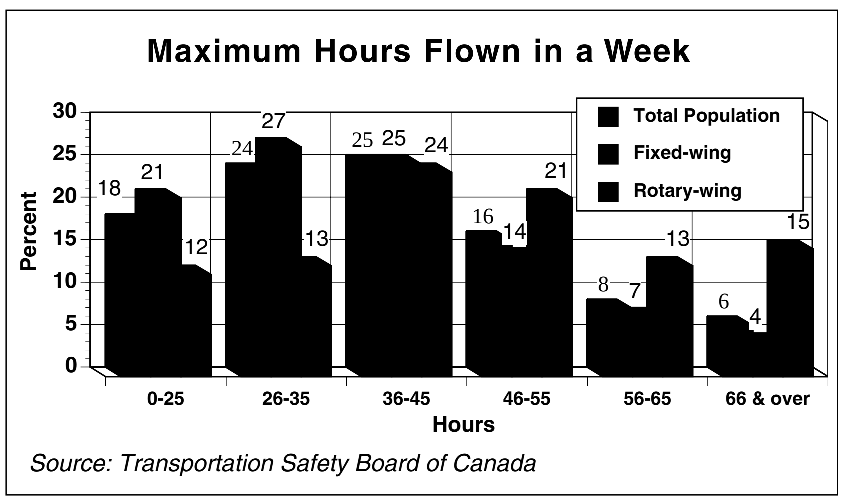

Figure 3

percent of the fixed-wing pilots. Ex-military pilots generally reported higher income than civilian-trained pilots.

Regarding flying training on the aircraft they normally fly, 63 percent of the respondents felt it was adequate, but 20 percent believed there should have been more. Twenty percent said that the introduction to company operations was not appropriate. A total of 14 percent reported that recurrent training never occurred or occurred less than once a year. Only 61 percent of the respondents believed that recurrent training was enough or more than required; 36 percent felt it was not enough or far too little.

On average, 50 percent of the pilots reported flying between zero to four hours daily, 37 percent five to seven hours and 8 percent eight to 10 hours (Figure 3). The mean was 4.8 hours. The mean of the average flying hours per week was 19.3. In a year, rotary-wing pilots reportedly flew less than their fixed-wing counterparts; only 14 percent flew more than 600 hours, while 29 percent of their fixed-wing colleagues flew more than 600 hours. The yearly mean for the group was 461.6 hours. Concerning days off and duty days, 45 percent of the respondents flew more than six consecutive days and 28 percent flew more than 12 consecutive days often or very often.

Globally, 10 percent of the respondents reported that they often or always felt pressure from their employer to fly when it was unsafe to do so, and 20 percent felt such pressure from clients and passengers (Figure 4). Pressure from the employer to fly in illegal conditions was reported by 11 percent of the respondents as occurring often or always; the same pressure from clients or passengers was felt by 17 percent.

Pressured to Fly

As many as 25 percent of the respondents reported not receiving a copy of the operations manual when they began to work for their current employer. When asked whether their employer encouraged them to record unserviceabilities on a sheet separate from the aircraft journey log, 36 percent of the respondents answered that was always the case, 13 percent almost always and 14 percent usually.

For 14 percent of the respondents, there were seldom or never adequate restraining devices to satisfactorily restrain cargo or baggage in a forced landing or an emergency procedure; 12 percent of the respondents always or almost always flew with unrestrained cargo. On the subject of cargo, 42 percent seldom or never had adequate weighing facilities available.

On the subject of weather facilities, 11 percent of the respondents usually flew without a weather briefing, and 11 percent always or almost always flew without a weather briefing. Rotary-wing pilots stand out in this respect; 20 percent usually flew without a weather briefing and 10 percent always or almost always flew without a weather briefing.

More Comments Offered

To obtain further insight, a comment section was added to the questionnaire. This allowed for the discussion of subjects that may not

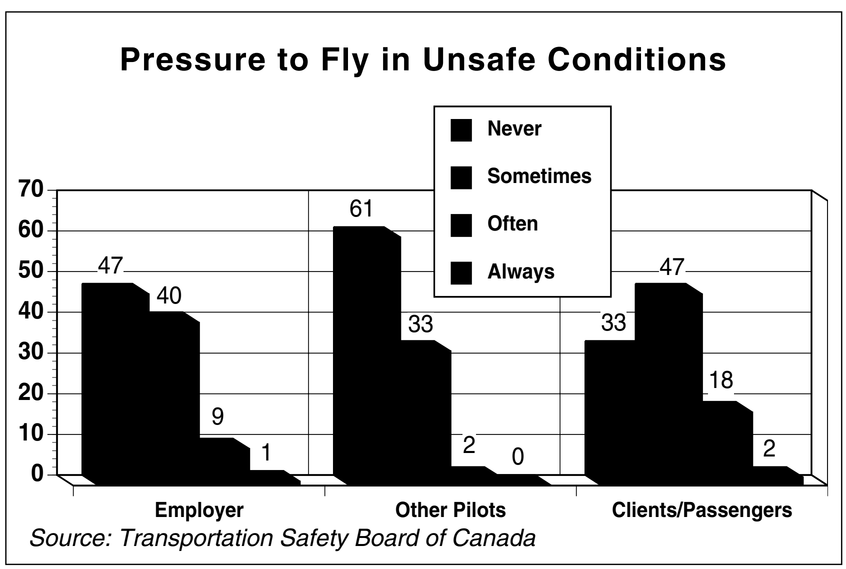

Figure 4

have been anticipated and for the expression of a subjective response to convey the intensity or nuances of an issue or problem.

The relationship of mutual dependence between pilots and air traffic controllers was seen by some respondents to be marred by lack of appreciation for the pilots' needs and workloads.

The U.S. air traffic control system is perceived as superior, one that many believe the Canadian system should emulate. The Canadian air traffic system is also viewed as another casualty of the recession, and safety is perceived by some as being compromised by fewer weather facilities, especially in sparsely populated northern regions.

Poor Economic Conditions Foster Unsafe Conditions

The comments suggest that some pilots are living near poverty, especially those in the northern regions, and those employed in the instructional fields. The potential to exploit this labor market is a viable option for employers because of the present economic conditions, of what is perceived as a lack of definition of "duty time" and of a love of flying that most of these pilots possess. In these times of recession, the abundance of pilots allows for company operators to be very selective in hiring. According to some respondents, the selectivity is often a function of a tolerant attitude toward dangerous practices and risk taking.

Numerous comments focused on perceived weaknesses of Transport Canada (TC) inspections because of advance notice. Loose ends at an operation can be tied up, books and logs completed or created, etc. by the time the inspectors arrive.

The overall feeling expressed by the respondents is that TC's effects are superficial, and that there is a meaningless emphasis on paper compliance. The perception is that a legal operation can be feigned.

The comments sometimes convey a feeling of frustration on the part of the pilots as shown by the following excerpt from one pilot's comments:

How is a co-pilot with 400 hours supposed to tell a chief pilot with 20,000 hours that an aircraft is overweight, out of center of gravity, with an improperly tied down cargo, that the aircraft shouldn't be flown, when this same chief has done it hundreds of times without any problem? (So has the president, and all he wants is money from charging a customer for two flights and only flying one.) If you can answer this, and allow me to keep the job I love more than anything, I'll do it. ♦

Publications Received at FSF Jerry Lederer Aviation Safety Library

by
Editorial Staff

Reports

Air Traffic Control: Justifications for Capital Investments Need Strengthening: Report to the Chairman, Subcommittee on Transportation and Related Agencies, Committee on Appropriations, House of Representatives. Washington, D.C. General Accounting Office (GAO)**, 1993. 27 p.: ill.

Keywords
1. United States — Federal Aviation Administration — Procurement Evaluation.
2. Air Traffic Control — United States — Automation.

Summary: This report examines the U.S. Federal Aviation Administration's (FAA) process for developing mission-need statements — statements that justify the need for an investment and state what the purpose of the investment is, how it will meet the agency's needs, what risks are involved and provide a sound basis for investment decisions.

As part of its $32 billion capital investment plan to modernize the air traffic control (ATC) system and enhance the safety and efficiency of air travel, the FAA reformed its acquisition process in February 1991. Some mission-need statements were disapproved and others were withdrawn. The report said many mission-need statements do not support the need for capital investments. Of the 25 mission-need statements examined, 110 deficiencies in the ATC system were listed, possibly costing $5 billion to fix. Moreover, nearly 60 percent of the deficiencies were merely assertions that the project could improve capacity or safety and should be acquired. These statements contained no quantitative or qualitative information explaining performance or maintenance problems or how new funding would reduce delays or maintenance expense. The statements were seldom based upon an analysis of mission performance.

The GAO said FAA officials will have to reorient their thinking to first analyzing current performance to identify deficiencies and the need for improved capabilities in its mission areas. The GAO recommends that the Secretary of Transportation direct the FAA to approve only those mission-need statements that are well supported with analytical evidence of current and projected needs and emphasize mission analysis as the starting point for acquisitions.

The report includes an appendix of the FAA's national airspace system service mission areas and examples of mission analysis processes.

Airspace System: Emerging Technologies May Offer Alternatives to the Instrument Landing System: Report to the Chairman, Subcommittee on Transportation and Related Agencies, Committee on Appropriations, House of Representatives. Washington, D.C. General Accounting Office (GAO)**, 1992. 39 p.: ill.

Keywords
1. Instrument Landing Systems.
2. Landing Aids (Aeronautics).
3. Microwave Landing Systems.
4. Airplanes — Landing — Technological Innovations.

Summary: As part of its capital investment plan to modernize the national airspace system, the U.S. Federal Aviation Administration proposes to replace the current ground-based precision landing system, the instrument landing system (ILS), with the new microwave landing system (MLS). Since the MLS decision was made, other alternatives for a precision landing system have emerged. The GAO was asked to review these alternatives, describe the capabilities and costs of these precision landing systems and identify some of the potential consequences of FAA's approach to developing these systems.

One alternative to the current system and the MLS system is an ILS enhanced with a computer-based flight management system (FMS) on board the aircraft. Another is based upon the U.S. satellite navigation system, the Global Positioning System (GPS), used in military applications and that would need to be enhanced for use in civil aviation. Each of these systems or mixture of systems have their benefits and drawbacks.

According to the report, some users have already installed avionics for the ILS/FMS combination and the satellite-based system to support aircraft operations, including navigation. They would prefer to use this equipment for precision landings, rather than make an additional investment in MLS equipment.

Since the costs of these systems will be substantial to FAA and users, the GAO and aviation industry representatives are concerned that although the FAA is devoting substantial resources to develop the MLS, the agency is committing an insufficient level of resources to develop the ILS/FMS combination and the satellite-based systems.

To determine which alternative precision landing system will best meet the requirements for precision landings, the GAO recommends that the FAA provide full budgetary support for the development of alternative systems for comparing the system's capabilities, benefits and costs; and prepare a mission-need statement for precision landing systems based on runway-to-runway determination of which system provides the most benefits at the lowest cost to both FAA and the system's users.

The report concludes with appendices on the costs and capabilities of the ILS and alternative precision landing systems under consideration.

Safety Study: Alcohol and Other Drug Involvement in Fatal General Aviation Accidents, 1983 through 1988. Washington, D.C. U.S. National Transportation Safety Board (NTSB), 1992. xi, 159 p. ill. Available through National Technical Information Service*.

Keywords
1. Aviation Toxicology.
2. Flight — Physiological Aspects.
3. Airplanes — Private Flying.

Summary: The NTSB conducted this study to examine alcohol and other drug involvement in fatal general aviation accidents that occurred from 1983 through 1988.

Collected data was used to compare the level of alcohol-involved accidents during this period with the level documented in the 1984 statistical review of alcohol-involved aviation accidents that occurred from 1975 through 1981. For all general aviation accidents that were fatal to the pilot-in-command, a comparison was made between those accidents in which alcohol and/or drugs was cited as a cause or factor and those accidents in which drugs or alcohol was not cited as a factor.

Comparisons were made for these two groups in accident characteristics, flight conditions, pilot-in-command characteristics and causes and factors.

During the 1983 through 1988 period, there was a downward trend in total general aviation accidents, fatal general aviation accidents, general aviation accidents fatal to the pilot-in-command, and alcohol-involved general aviation accidents fatal to the pilot.

According to the study, there was a decrease in the percent of toxicological tests that were positive for fatally injured general aviation pilots from about 10 percent in the mid-1970s to about 6.0 percent in the late 1980s. The blood alcohol concentration (BAC) of pilots fatally injured in alcohol-involved accidents remained high; the mean BAC of alcohol-positive pilots was nearly four times the BAC offense level established by the current U.S. Federal Aviation Administration regulations.

The study also addresses the need for comprehensive state laws pertaining to alcohol and drug use in general aviation, and the need to prevent pilots from flying while impaired by alcohol or other drugs.

The study includes appendices on excerpts from *General Operating and Flight Rules Related to Alcohol and other Drugs; Status of NTSB Safety Recommendations Related to Alcohol and other Drugs in Transportation; General Aviation Data Tables; Drugs Detected in General Aviation Accidents 1983 through 1988; and Federal Aviation Regulations Related to Offenses Involving Alcohol or Drugs*.

Light Aircraft Maintenance: General Guidance on Implementation of the Light Aircraft Maintenance Scheme (LAMS), for Aircraft not Exceeding 2730 kg MTWA, with a Certificate of Airworthiness in the Transport, Aerial Work or Private Category, CAP 520. London: U.K. Civil Aviation Authority (CAA), 1993. v, 50 p. Available through the CAA***.

Keywords
1. Airplanes, Private — Maintenance and Repair.
2. Great Britain — Civil Aviation Authority.

Summary: This second edition of the May 1986 CAA Civil Air Publication (CAP) contains guidance material for the servicing and maintenance of aircraft not exceeding 2,730 kilograms (6,006 pounds). This publication consolidates all earlier information leaflets issued during the introduction of the LAMS schedule to guide industry in methods of meeting published requirements and bring them up to date in one document.

This guide is divided into sections covering owner and operator responsibilities, approval of organizations to carry out maintenance checks, maintenance schedules, log books, pilot maintenance, airworthiness flight tests, and engineering support arrangements for holders of air operator's certificates (AOC).

Each section has an appendix of sample forms for inspection, certification and maintenance log book entries. A checklist of items, taken into account during assessment of suitability for approval of organizations to carry out maintenance checks, is also included.

Books

The Airline Passenger's Guerrilla Handbook: Strategies & Tactics for Beating the Air Travel System/ George Albert Brown. Washington, D.C. Blakes Publishing Group, 1989. xviii, 396 p.: ill.

Keywords
1. Air Travel — Handbooks, Manuals, etc.

Summary: Strategies have been collected from examination of loopholes in airlines' rules that might allow passengers to carry on or check in more baggage than the airline's restrictions would appear to allow, or allow passengers to receive refunds on nonrefundable tickets.

The handbook's contents include chapters on choosing flights for the fastest trip; choosing flights for comfort, convenience and safety; choosing flights for the cheapest air fare; packing for air travel; getting to the airport; waiting in the airport; getting onto the plane; the basics of cabin life; getting away from the airport; and dealing with special problems of air travel.

Appendices on selected U.S. airport phone numbers and airline toll-free phone numbers are also included. ♦

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Accident/Incident Briefs

by
Editorial Staff

This information provides an awareness of problem areas 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.

Unsecured Cargo Door Opens During Initial Climb

Boeing 737-200. Minor damage. No injuries.

At 1,500 feet (454 meters) during a night departure at take-off power, the crew heard a bang from the right engine. At the same time, the forward hold door warning light illuminated.

The flight crew reduced engine power, and no abnormal engine indications were noted. Nevertheless, efforts to restore power were unsuccessful and the engine was shut down. The aircraft landed without incident.

An investigation determined that the forward hold door was open and that the nose cone was missing from the right engine. There was, however, no evidence of ingestion and all hold baggage was accounted for. Maintenance and quality control personnel were cited for failure to ensure that the cargo door was locked.

Strong Gust Blows Aircraft Off Runway on Touchdown

Boeing 767-200. Substantial damage. No injuries.

The pilot was executing a coupled instrument landing system (ILS) Category I approach at night. The autopilot was disengaged at 260 feet (79 meters) above ground level and the aircraft was aligned on the centerline at the runway threshold.

Just before leveloff and touchdown, the aircraft was buffeted by a sharp gust from the left and the right main landing gear touched down outside the runway edge lights. The aircraft continued to depart the runway and came to rest alongside it with all wheels in the mud. The runway was closed for more than 24 hours.

An inquiry concluded that the pilot failed to sufficiently adjust for the unexpected gust.

Turbulence Pounds Airliner; Injures Cabin Crew

BAe 146-300. Minor damage. One minor injury.

While climbing through 14,000 feet (4,242 meters), the aircraft encountered unexpected and severe clear air turbulence lasting nearly 10 seconds. The autopilot disengaged and although pitch and roll attitudes were not significantly disturbed, the captain reported a strong disturbance in vertical and lateral acceleration.

The cabin crew, engaged in serving drinks, were thrown off their feet. One flight attendant struck the cabin roof before falling against a bulkhead and fractured her elbow.

The weather forecast obtained by the crew prior to the flight had included a warning of severe turbulence reported at 17,000 feet and 32,000 feet (5,151 meters and 9,697 meters).

Air Taxi
Commuter

Stall Recovery Leads to Forced Landing

Fokker F27 Friendship. Aircraft destroyed. Two serious injuries.

The F27 was on approach to land when the stall warning horn sounded. During recovery, both engines stopped and the pilot made a forced landing. The aircraft was destroyed by fire after impact.

An inquiry determined that both engines had overheated. The No.2 engine separated from the wing because of vibration and was found about three kilometers from the accident site. A report cited improper operation of propeller controls and poor crew coordination as contributing causes to the accident.

Steep Approach Ends Short of Runway

Britten-Norman Islander. Substantial damage. No injuries.

After flying several short legs, the pilot elected to land on runway 09 at the destination airport, where winds were reported 160 degrees at 10 knots. The runway was 1,250 feet (379 meters) long with a slight downslope. A slope of nearly 40 degrees led to the runway threshold.

On short final, in the correct landing configuration, the twin-engine aircraft sank rapidly. Despite application of full power, it struck an embankment 10 feet short (3 meters) and two feet (.6 meter) below the runway threshold.

An inquiry determined that the accident was caused by an approach steeper than usually made to a level runway, with a lower power setting, and the captain's desire to touch down close to the threshold of a short runway with little headwind.

Air Taxi
Commuter

Learjet Flown into Sea After Go-around

Gates Learjet 25. Aircraft destroyed. Two fatalities. Two minor injuries.

The pilot attempted a daylight instrument approach but was too high and decided to go-around. He then attempted a visual approach. Weather conditions were drizzle and rain with a ceiling of 2,970 feet (900 meters).

On final, the aircraft collided with the water, wings level in the landing configuration. The two crew members and three of the five passengers on board escaped. Two passengers were killed. The aircraft sank inverted. The airport was located near the shore of a bay along the South Atlantic coast.

An investigation determined that the pilot misjudged his altitude, disregarded decision height procedures and failed to monitor his position visually.

Baron Plunges On VOR Approach

Beech 58 Baron. Aircraft destroyed. Two fatalities.

The aircraft was attempting a VOR/DME approach to runway 21 with a circle to land on runway 3. The Baron descended out of the overcast in a near vertical nose-down attitude.

The aircraft impacted on a highway about one mile north of the approach end of runway 3 and was destroyed by fire. Weather at the time of the accident was 700 feet (212 meters) overcast, visibility one mile (1.6 kilometers) in light snow showers and fog, and wind 050 degrees at 15 knots gusting to 20 knots. An inquiry determined that the pilot likely suffered from spatial disorientation before the crash.

Other General Aviation

Runaway Cessna Collides with Trees

Cessna 185. Substantial damage. No injuries.

After landing and dropping off two passengers, the pilot had difficulty restarting the Skywagon's engine. The pilot then attempted to start the engine by hand turning the propeller.

When the engine started, the aircraft was not adequately secured and taxied without the pilot into trees a short distance away. The crash seriously damaged both wings.

Power Loss During Practice Flight Injures Two

Cessna 152. Aircraft destroyed. Two serious injuries.

After a practice forced-landing exercise, the Cessna's engine lost power during the go-around at an altitude of 50 feet (15 meters).

The aircraft stalled when the pilot attempted to avoid trees and power lines. The aircraft impacted the ground in a nose-down attitude, seriously injuring the student pilot and instructor.

An investigation determined that the field in which the aircraft crashed sloped up in the direction of the attempted go-around at an angle similar to the climb gradient of the aircraft.

Rotorcraft

Wire Strike Destroys Bell 206B

Bell 206B. Aircraft destroyed. One fatality.

The helicopter was on an aerial application mission near a utility right-of-way when it struck wires and crashed. The aircraft caught fire after impact and the pilot, the sole occupant, was killed.

The herbicide spraying mission was being conducted in visual meteorological conditions.

Vertigo Cuts Short Search-and-Rescue Operation

Hughes OH-6A. Substantial damage. Two minor injuries.

The helicopter departed the airport at 0410 on a search-and-rescue mission for a downed military airplane. The two pilots held commercial certificates but were not instrument rated.

The pilot-in-command said he elected to make the takeoff with both the landing light and the "night sun" search light on. Shortly after takeoff, at about 300 feet (91 meters) above ground level and with no visible horizon or ground reference, the pilot developed severe spatial disorientation.

The pilot applied collective pitch and aft cyclic prior to ground impact. The aircraft bounced twice before coming to rest. The helicopter received substantial damage and the two pilots suffered minor injuries. The weather was clear with 10 miles (16 kilometers) visibility.

Steep Turn Snares Hiller

Hiller FH-1100. Aircraft destroyed. One fatality.

The helicopter was returning to its home base at night when it collided with the ground and caught fire.

Witnesses reported seeing the aircraft flying at low altitude, and physical evidence revealed that the first ground impact was made by the main rotor blades while the helicopter was in a left bank. The helicopter crashed in a ditch and the airframe was destroyed. The pilot was killed in the crash. Visual meteorological conditions were reported at the time of the crash.♦