Flight Safety
DIGEST

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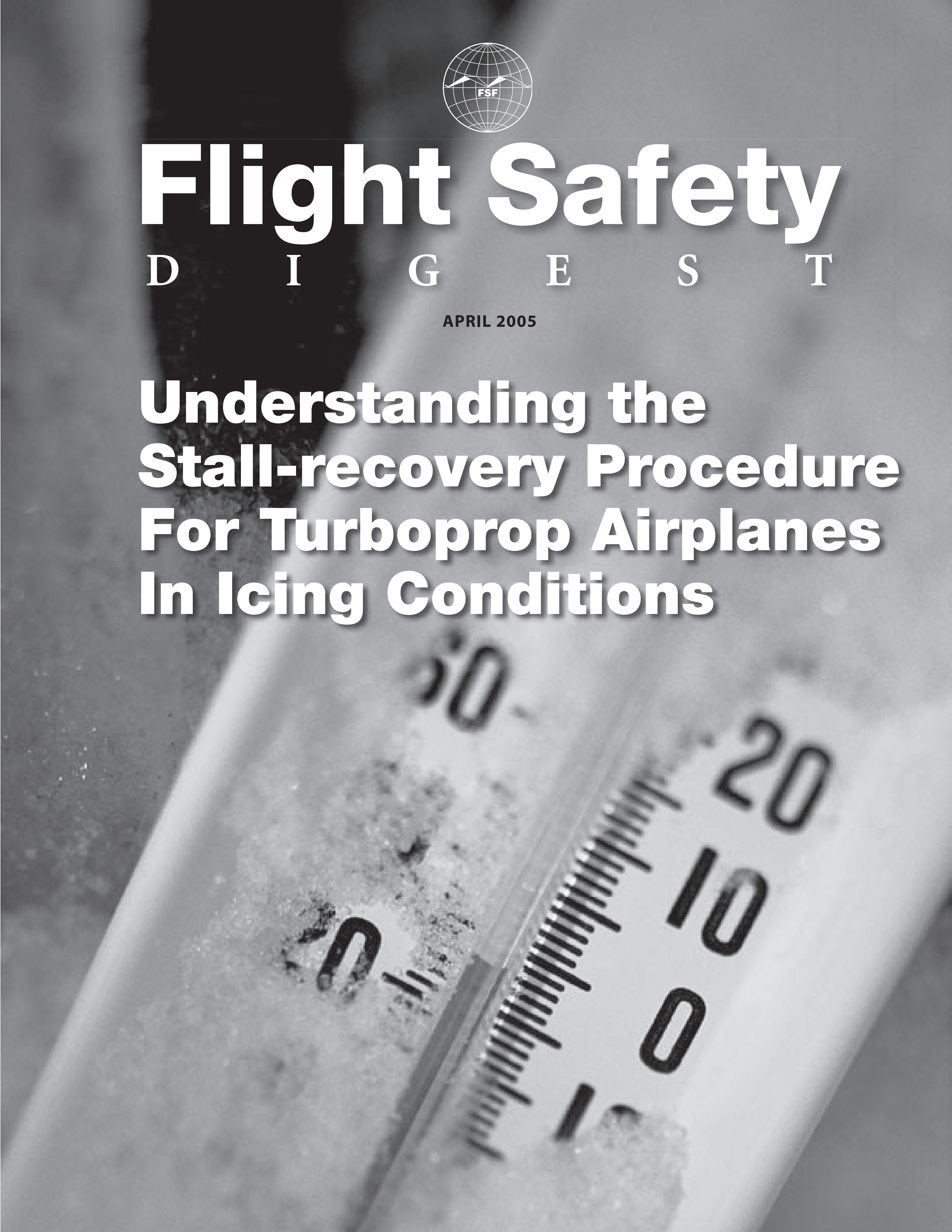
Understanding the Stall-recovery Procedure For Turboprop Airplanes In Icing Conditions



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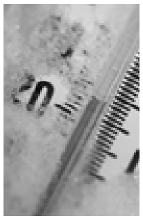

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Understanding the Stall-recovery Procedure for Turboprop Airplanes in Icing Conditions

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Supercooled large droplets froze instantly on contact with a side window in the airplane cockpit during an icing test flight.

(Source: John P. Dow Sr.)

Understanding the Stall-recovery Procedure for Turboprop Airplanes in Icing Conditions

Current pilot training typically emphasizes powering through a stall recovery with no loss of altitude. Nevertheless, when flying a turboprop airplane that has accumulated ice, lowering the nose to reduce angle-of-attack is imperative. Here's why.

— JOHN P. DOW SR.

Most encounters with icing conditions in turbopropeller-driven (turboprop) airplanes are relatively benign and demand little more than promptly activating the airplane's ice-protection systems and finding an ice-free altitude. Nevertheless, there have been encounters with icing conditions that have caused rapid and adverse airplane responses, including stalls that have led to airplane upsets and loss of control. A broader understanding of what might be required for stall recovery will better prepare a turboprop airplane pilot to respond to one of these infrequent but very dangerous icing encounters.

An *airplane upset* is defined by the *Airplane Upset Recovery Training Aid* as including the following unintentional conditions: "Pitch attitude greater than 25 degrees nose-up; pitch attitude greater than 10 degrees nose-down; bank angle greater than 45 degrees [or] within the above parameters but flying at airspeeds inappropriate for the conditions."[1] The training aid says that specific values may vary among airplane models.

Loss of control is defined by the European Joint Aviation Authorities (JAA) Safety Strategy Initiative as "a situation in which the crew fail[s] to maintain/regain control of an aircraft. This can result from external factors, such as icing or mechanical failures."[2]

The U.S. Commercial Aviation Safety Team has a similar, but broader, definition: "Loss of control refers to accidents resulting from situations in which the pilot should have maintained or regained aircraft control but did not."[3]

"Recovery from icing-induced rolls and more complete stalls requires trading altitude for airspeed."

Examination of digital flight data recorder (DFDR) data from turboprop airplanes involved in ice-related loss-of-control accidents has shown some common characteristics. For example, in three fatal accidents that resulted in 134 total fatalities, the pilots initially did not reduce wing angle-of-attack (AOA) by moving the control column to the nose-down position early in the upset sequence. The accidents involved an Avions de Transport Regional ATR 42 in Crezzo, Italy, in 1987;[4] an ATR 72 in Roselawn, Indiana, U.S. in 1994;[5] and an Embraer Brasilia in Monroe, Michigan, U.S., in 1997.[6]

The DFDR data from the three accident airplanes show that AOA either remained close to the angle at which airflow separation occurred or that AOA increased, compounding the severity of the upset and making recovery more difficult and unlikely. Other ice-related incidents from which flight data were available also involved AOAs that were maintained or increased.

The scenario that was involved in the Roselawn accident was duplicated in a flight simulator during a study conducted for the U.S. National Aeronautics and Space Administration (NASA).[7] The subjects for the study were 40 newly hired airline pilots; fewer than half were able to recover. The researchers said that a primary factor in successful recovery was nose-down elevator input. Their report said:

> *The pilots appeared to respond in accordance with their training for excessive bank and stall recovery, but they did not implement corrective actions uniquely required for icing-induced roll and uncommanded control movement. These two types of recoveries require different responses: Normal stall-recovery training (which trains pilots in recovering from the approach to stall) emphasizes applying maximum power and minimizing loss of altitude. In contrast, recovery from icing-induced rolls and more complete stalls requires trading altitude for airspeed.*

Fly Like You Train (Usually)

Most ice-related stalls and upsets occur in instrument meteorological conditions (IMC). Instrument interpretation (e.g., when the airplane is in an unusual attitude) requires skills that pilots typically have not developed in training or from experience. Moreover, because an ice-related stall typically occurs at a lower-than-normal AOA (and higher-than-normal airspeed), the stall can surprise the pilot.

Pilots of turbine airplanes typically are trained in flight simulators to respond to the first indication of a stall by applying power and maintaining pitch attitude, with the objective of losing no altitude during recovery. Thus, in theory, the airplane will accelerate to an increased airspeed and a reduced AOA. The procedure results in recovery in the simulator; nevertheless, the procedure will not always result in recovery in an airplane with flight characteristics degraded by ice.

The training follows U.S. Federal Aviation Administration (FAA) practical test standards (PTS). The PTS for the private pilot certificate and the PTS for the commercial pilot certificate, for example, specify a "minimum loss of altitude" during stall recovery.

The PTS for the airline transport pilot certificate and for aircraft type ratings require recovery to be initiated at "the first indication of an impending stall" and to be completed with "acceptable" altitude loss. The JAA standards are similar.

AFM Procedures Vary

Some airplane flight manuals (AFMs) and flight crew operating manuals (FCOMs) include recommended stall-recovery procedures, although the information is not required. The FCOMs for the ATR 42 and the ATR 72, for example, recommend the following procedure for a "stall without ice accretion":[8]

> *Recovery of stall approaches should normally be started as soon as a stall alert is perceived: a gentle pilot push [on the control column] (together with power increase if applicable) will then allow instant recovery.*

The FCOMs for the ATR 42 and the ATR 72 recommend the following procedure for a "stall with ice accretion":

> *Recovery of stall in such conditions must be started as soon as stall warning is activating or buffeting and/or beginning of lateral instability and/or sudden roll-off is perceived. Recovery will be best accomplished by: a pilot push on the wheel as necessary to regain control; selection of flaps 15; [and] increase in power, up to MCT [maximum continuous thrust] if needed.*

"To my knowledge, it has always been ATR standard policy to recommend a pitch-down command for stall recovery, as well as applying power," said Gilbert Defer, former vice president of flight test for ATR.[9] "Furthermore, for stall in icing conditions, ATR has always recommended extension of the flaps to the first notch as the most rapid and efficient manner to reduce AOA dramatically."

Most AFMs and FCOMs, however, do not recommend a recovery procedure for an ice-related stall. The manuals for the Raytheon Beechcraft King Air models, for example, include only a recommended procedure for recovery from a non-ice-related, single-engine stall.[10]

Dave Fisher, senior air safety investigator for Bombardier Aerospace, said, "There is nothing in our manuals [for the Dash 8] about stall recovery because there's no requirement for it to be in there. However, stall-recovery technique is covered during initial and recurrent pilot training and practiced in the Dash 8 flight simulator."[11] Nevertheless, the PTS standards — primarily those for the ATP certificate and airplane type ratings — typically are adhered to during training.

"It doesn't make much difference what the manufacturers recommend, the pilots that fly the airplanes must get a check ride from the FAA and perform the required procedures," said Jon Hannan, former flight test pilot for the FAA Small Airplane Directorate.[12]

The PTS "acceptable-altitude-loss" standard, which typically is interpreted as zero altitude loss during training, is designed to avoid terrain contact during stall recoveries at low altitude.

"Most stalls occur on approach or on takeoff, when you don't have a lot of altitude to spare; the idea is to conserve altitude during recovery," said Daniel Meier Jr., aviation safety inspector, flight operations, at FAA headquarters.[13] "A stall caused by icing is extremely hazardous because you cannot conserve altitude by maintaining attitude."

Trade Altitude for Airspeed

Adhering to the standard of minimum altitude loss ingrained in training has resulted in pilots failing to recover from ice-related stalls and upsets that have resulted in altitude losses in excess of 9,000 feet in turboprop airplanes.

Pilots of turboprop airplanes should be taught that they might need to trade some altitude for airspeed if the airplane stalls during flight in icing conditions. Research has shown that an immediate and complete recovery from an ice-related stall likely will be accomplished by using the following:

- At the first sign of a stall — whether activation of the stick shaker, uncommanded roll, buffet or other aerodynamic cues — apply nose-down pitch control and level the wings while increasing propeller speed and torque until a sufficient increase in airspeed (decrease in AOA) is attained. In most

"A stall caused by icing is extremely hazardous because you cannot conserve altitude by maintaining attitude."

events, the nose will drop as a consequence of the stall, but it will result in an insufficient decrease in AOA, requiring further nose-down pitch change. (The unanticipated sensations accompanying this pitch change might be uncomfortable for the pilot);

- If the nose cannot be lowered, extend the flaps from the cruise configuration to the first setting and then lower the nose to increase speed as appropriate for the airplane type and configuration; and,
- Recover. Retract the flaps, as appropriate.

"This is absolutely correct," Meier said. "If you are in icing conditions and experience a loss of airspeed, a need for more power, diminished controllability and/or diminished performance, it's a pretty good indication that you are picking up ice and not shedding it. If, all of a sudden, the airplane falls out of the sky, you've stalled because of ice, and the recovery should be nose-down, wings level and full power."

Training specialists at FlightSafety International, CAE SimuFlite and SimCom agree.

"[This] is 100 percent correct," said Dan Orlando, director of training at the FlightSafety International Raytheon Training Center.[14] "Our recommended procedure for stall in the King Air is to lower the nose and add power simultaneously."

The stall and upset occurred at stick-shaker activation or prior to stick-shaker activation in ice-contaminated airplanes.

Chris Litherland, manager of CAE SimuFlite's King Air program and Beechjet program, said, "Although applying maximum power and relaxing back pressure may be sufficient for a normal stall recovery, it is logical that in icing conditions, you also may need to lower the nose to compensate for the aerodynamic changes the ice has caused."[15]

Charles Parker, coordinator of SimCom's King Air 90–series program, said, "The normal stall recovery — that is, when you know you're not in icing conditions — is to try to maintain your altitude and power out of it. But, if you're in icing conditions, you must increase your airspeed, and the only way you're going to do that is to drop the nose."[16]

Autopilot Masks Cues

In training, the visual cues or tactile cues of impending stall that are presented to the pilot typically consist of stick-shaker (stall-warning) system activation. Nevertheless, there have been some events in which the stall and upset occurred at stick-shaker activation or prior to stick-shaker activation in ice-contaminated airplanes. Additionally, other valuable cues such as aerodynamic buffet were ignored or misinterpreted as propeller vibration.

With the autopilot engaged, the pilot is "out of the loop" in "feeling" the responsiveness of the flight controls. Moreover, as ice accumulates, the autopilot might be required to trim the controls against the adverse aerodynamic effects of the ice. An instantaneous and substantial control input might surprise the pilot if the autopilot reaches its trim-force limits and disengages unexpectedly. The pilot might be similarly surprised by unexpected control inputs that might be masked by the autopilot until the autopilot intentionally is disengaged.

Airplane response and kinesthetic cues to an ice-related stall can be substantially different from the simulator-training scenario. An ice-related stall produces less buffet in some airplanes in some configurations than a non-ice-related stall; in other airplanes, greater buffet occurs or the buffet begins earlier in an ice-related stall. The cues also can be inconsistent in the same airplane with different flap settings.

Hannan said, "The pilot should hand fly the airplane in icing conditions that are severe enough to effect a slowdown because the first indications of stall — mushy control feel and/or small oscillations — usually can be felt in time to recover prior to a stall. If a stall occurs, it is vitally important to decrease the AOA quickly, push the nose down or lower flaps, and apply power to accelerate to a higher airspeed."

Parker said that when an ice-related stall begins to occur, "you feel the airplane rumble, and you're losing altitude. You have to push the nose over when you feel that and add maximum available power. When you do, the airplane will start flying again."

Some turboprop airplanes are equipped with stick-pusher systems that lower the nose when AOA reaches a critical (pre-stall) value. Some airplanes are equipped with stall-protection systems that reduce the threshold AOA for stick-shaker activation and stick-pusher activation when ice-protection systems are activated. The Dash 8 300 and Dash 8 Q400, for example, have modifications that enable the pilot to select an "increase Ref speed switch," which will cause the stick-shaker to activate at a higher speed during flight in icing conditions.[17]

Insufficient Excess Thrust

Turboprop airplanes affected by ice-induced drag typically do not have the substantial excess thrust of large jet transports that is implicit in the power-up and maintain-pitch procedure.

In addition to increasing drag and causing airflow separation, ice has an adverse effect on the propellers.

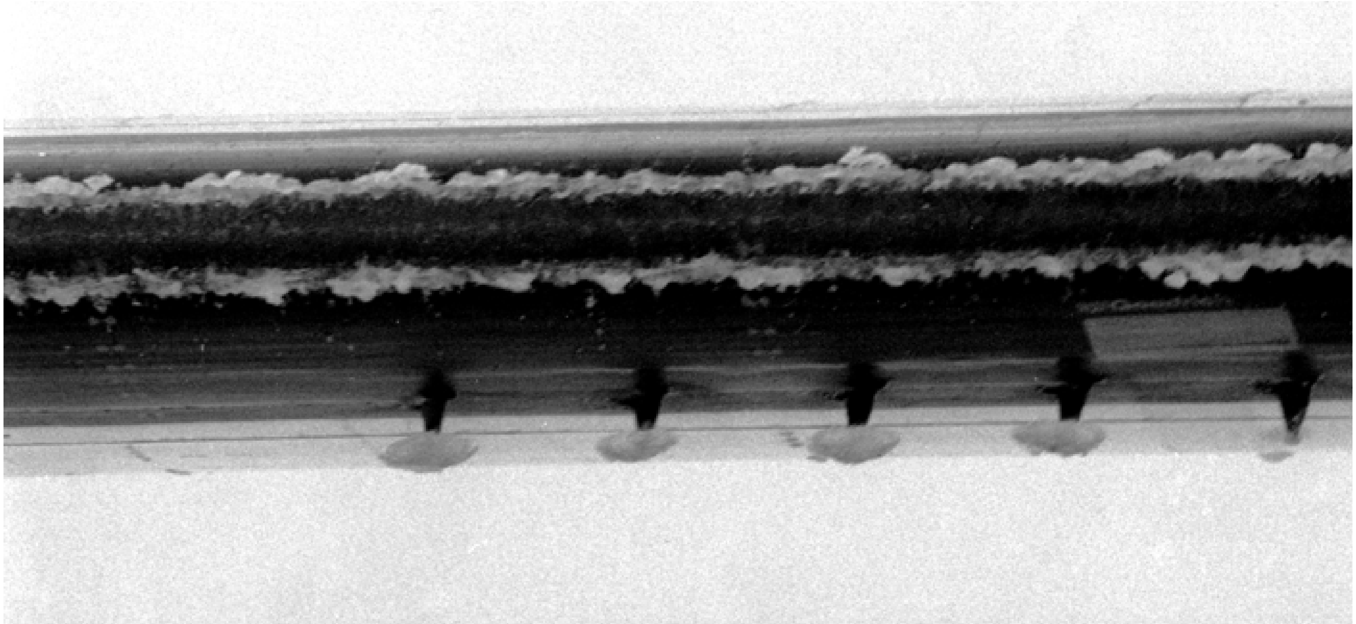
During the upset that led to the loss-of-control accident at Monroe, the crew at one point increased engine torque 150 percent. Although increasing torque would seem beneficial, analysis of propeller thrust versus torque shows that propeller blades begin to stall at the large blade-pitch angles associated with high torque values, thus producing substantially less than 100 percent thrust — in some events, as low as 85 percent thrust.

Moreover, unclearable contamination (i.e., ice on unprotected surfaces) of the propeller blades also might reduce thrust; tests have shown that unclearable contamination can reduce thrust by 20 percent.

Ice Reduces Stall AOA

Icing redesigns the airplane (see photo below). A review of what can occur to airplane aerodynamics in severe icing encounters improves understanding of what is required for stall recovery. The first effect of ice accumulation usually is a reduction of the stall AOA (and an increase in the stall speed). There is no way for the pilot to know what the resulting stall AOA is at any given moment.

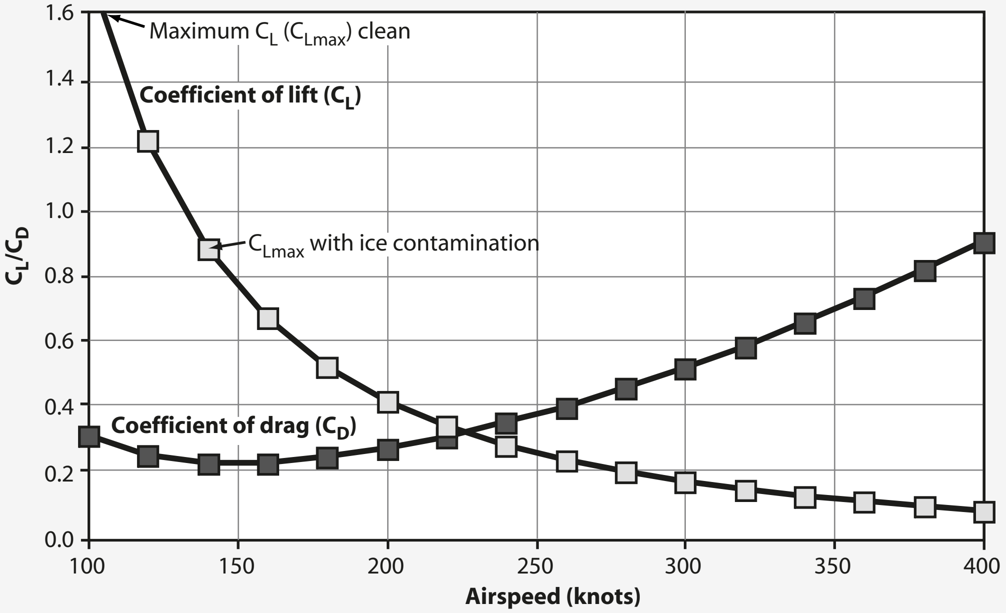
Figure 1 (page 6) shows how lift can vary with airspeed in unaccelerated flight. The data on lift coefficients were derived from DFDR data from a British Aerospace ATP that was involved in an ice-related upset in August 1991. In cruise configuration and uncontaminated, the airplane has a maximum coefficient of lift (C_{Lmax}) — which corresponds to the stall AOA and, in this



Ridges of ice formed on the leading edge of the horizontal stabilizer, and mushroom-shaped ice caps formed on the vortex generators below the stabilizer during a research flight in a de Havilland Twin Otter. The ice was not a hazard during the flight. (Photo: U.S. National Aeronautics and Space Administration)

Figure 1

Effect of Ice Contamination on Lift and Drag



Source: John P. Dow Sr.

illustration, to the stall airspeed — of nearly 1.6. With the ice contamination involved in the incident, C_{Lmax} was 0.9. Thus, the airplane's normal stall speed was about 110 knots; the ice-induced stall occurred when airspeed was reduced to about 140 knots.

As ice accumulates, drag increases. The increased drag might be evident early in the icing encounter; however, in some events, including the accident at Roselawn, the drag increase was calculated to be only 5 percent to 10 percent. In cruise flight, with the autopilot engaged in altitude-hold mode and with a constant power setting, airspeed will decrease and the autopilot will trim the airplane nose-up to maintain the selected altitude. If this is allowed to continue until AOA reaches the new (lower) stall AOA, flow separation will occur. The result can be an upset.

During climb, increased drag might be evident by an unexplained decrease in indicated airspeed and/or rate of climb (vertical speed). These indications demand immediate action by the pilot; if increased propeller speed and increased power do not return the airplane to safe speeds, an immediate descent is required. This is an emergency.

Ice-related upsets have occurred at the top of descent, most likely when power was reduced before the descent was begun. Accompanying power reduction is a reduction of the velocity of airflow over the wing; the beneficial effects of prop wash are reduced, and flow separation occurs at a much lower AOA. The preventive measure for this situation is to lower the nose, allow airspeed to increase, then adjust engine power and pitch trim for the descent.

Even without partial propeller-blade stall, reduced thrust caused by uncleared ice on the propeller blades combined with increased ice-related drag overall is a double penalty for a turboprop airplane, compared to an uncontaminated airplane that has substantial excess thrust. With partial propeller-blade stall involved, the disturbed flow field aft of a stalled blade section further degrades the aerodynamics of the wing.

Extending Flaps Can Help

An incident involving an upset in a Brasilia on March 5, 1998, illustrates the effectiveness of lowering the nose to reduce AOA. DFDR data recovered by the U.S. National Transportation Safety Board (NTSB) show that the upset occurred as airspeed decreased in a turn at 10,000 feet. The pilot initially was unable to recover by increasing power (e.g., increasing torque to 100 percent) and maintaining pitch attitude. He was able to recover after extending the flaps to the approach setting, which increased the lift coefficient, and lowering the nose, which reduced AOA.

The incident illustrates several important points:

- The initial power increase to 100 percent torque and a later, momentary, power increase to nearly 150 percent torque did not increase airspeed sufficiently to enable recovery;
- Nose-up pitch trim was used. The control column was not moved to the nose-down position until the flaps were extended; the pitch angle did not change substantially while airspeed was low;
- Before the upset occurred, the airplane was banked about 25 degrees left. It then rolled about 65 degrees right and about 45 degrees left. When the flaps were extended and propeller speed was increased at approximately 100 percent torque, the roll oscillation was reduced substantially even though pitch attitude was held relatively constant to the pre-upset value and airspeed had decreased to approximately 125 knots; and,
- In the recovery, the airplane climbed approximately 700 feet above the altitude at the beginning of the upset.

Myth of 'Safe Ice' Persists

The accident/incident record shows that pilots sometimes make incorrect or inappropriate decisions, which might be based on a lack of accurate and thorough knowledge about flight in icing conditions. The assumption is that pilots are capable of accurately discerning which ice is likely to be lethal and which ice is not, and how their airplane will perform in icing.

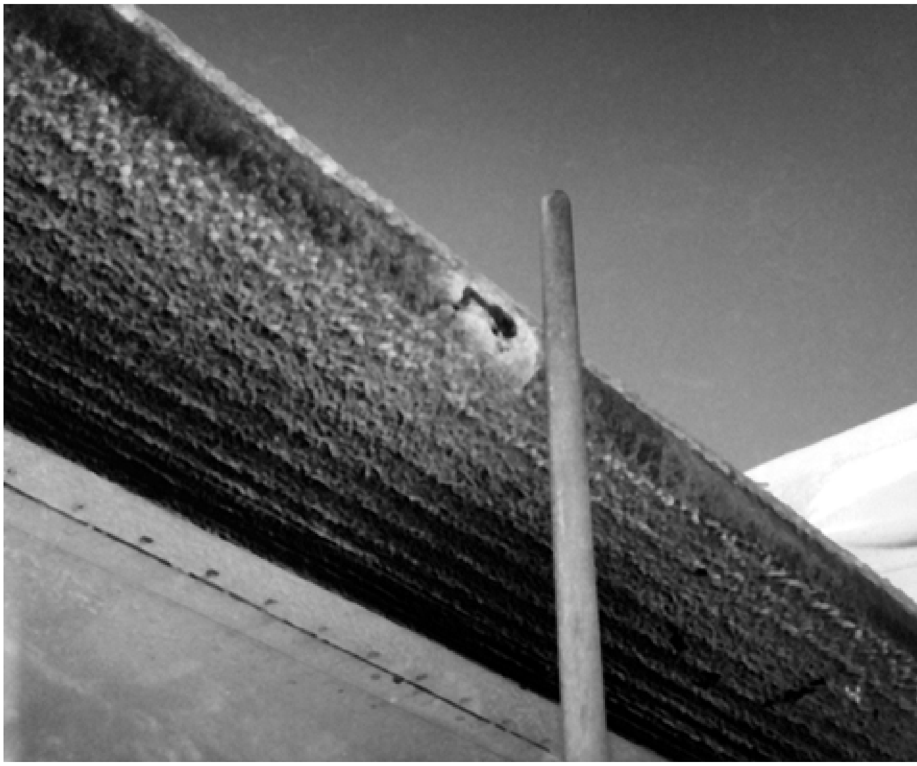
A persistent myth is that pilots can discriminate between "safe ice" and "unsafe ice" from visual inspection, even from a remote vantage point such as the flight deck. The following comments by a Convair 340 pilot appeared in a 1964 issue of *Air Line Pilot* magazine:

> *We encountered moderate icing climbing up through to on top. … There was a considerable amount of runback [ice]. … This really wasn't any problem. Hasn't every pilot landed an airliner with considerable ice or runback [ice] on it?*

This report, by a Saab 340 pilot, appeared in a 1993 issue of the magazine:

> *[The airplane had] a layer of light rime with a layer of clear on top. The FO [first officer] queried the captain if blowing the [deicing] boots was warranted, … which the captain declined.*

In 1993, a Saab 340A accumulated ice during an approach to Hibbing, Minnesota, U.S. The NTSB report said that the first officer (the pilot flying) asked the captain if he wanted to "pop the boots" to remove ice from the wings. The captain said, "It's going to the hangar. I'll run them on the ground." A high sink rate developed, and the airplane was substantially damaged in the subsequent hard landing (see photo below).[18]



Investigators used a broom handle to crack the ice on a Saab 340A's wing so that they could gauge the thickness of the ice. The airplane had been substantially damaged during a hard landing at Hibbing, Minnesota, U.S., in 1993; none of the 31 occupants was injured. (Photo: U.S. National Transportation Safety Board)

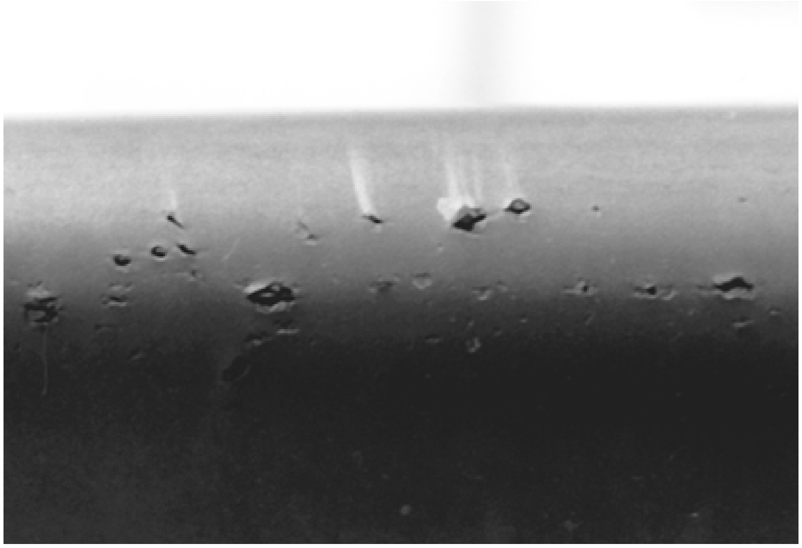
During an icing test flight, some ice remained after activation of the deice boots of a Mitsubishi MU-2 in addition to the uncleared ice on unprotected areas of the MU-2's wing-tip fuel tank and fairing.

(Photo: U.S. Federal Aviation Administration)

More recent events show that similar attitudes are held by some pilots and suggest that additional education and training are required to correct a misperception that apparently is a product of inconsequential experience with ice.

Use the Boots

On turboprop airplanes, ice typically is removed from the leading edges of the wings and the tail by deicing boots that crack it with mechanical force; the particles of ice then are carried away by the airflow (see photo upper right). Part of this process occurs during inflation, and part occurs during deflation.



Holes from age-related deterioration of deicing boots can allow water to be ingested by the vacuum pressure that holds the boots against the airfoil. Trapped water can freeze in the pneumatic plumbing and prevent inflation of the boots.

(Photo: John P. Dow Sr.)

Adequate care of deicing boots and the associated pneumatic system is important. Damage (e.g., cuts, tears) and age-related deterioration can reduce substantially the effectiveness of boots (see photo bottom left).

Modern deicing boots operate at pressures near 20 pounds per square inch (one kilogram per square centimeter) and have inflation tubes approximately 1.0 inch (2.5 centimeters) in diameter. Older tubes are nearly twice that size, have four times the volume and operate at lower pressures.

The current recommended practice of allowing ice to build to a thickness of 1/4 inch to 1/2 inch (approximately 2/3 centimeter to one centimeter) before activating the deicing boots results in a higher percentage of ice being removed on the first cycle of the boots. The 1/4-inch thickness can be used as a guideline at temperatures close to freezing — that is, from approximately minus 5 degrees Celsius (C; 23 degrees Fahrenheit [F]) — in which water droplets freeze relatively slowly on contact with the airplane and therefore contain relatively little air; thus, the ice is denser. Because the water droplets freeze relatively quickly at lower temperatures — below approximately minus 10 degrees C (14 degrees F) — the ice contains more air and, thus, is more brittle. In addition, at colder temperatures, the ice adheres more tenaciously to the boot; the adhesion is less at warmer temperatures. Thus, allowing colder ice to accrete to a greater thickness (1/2 inch) before operating the boots results in more ice being removed during the cycle.

Tests conducted by deicing-boot manufacturers Aérazur-Zodiac and Goodrich Corp. have shown that when boots are operated with less than 1/4 inch of ice in temperatures close to freezing or with less than 1/2 inch of ice in colder temperatures, a noticeable amount of ice (residual ice) remains on the boots after the first cycle; little residual ice remains on the boots after approximately the third cycle.[19]

FAA-sponsored tests have shown that when boots are activated in a continuous-cycling mode at the first sign of ice accumulation, the residual ice is less harmful than allowing 1/4 inch to 1/2 inch of ice to accumulate before boot activation. Nevertheless, the airplane manufacturers' instructions for using ice-protection systems must be followed. The point is: Use the boots.

Gauging Ice Severity

The FAA *Aeronautical Information Manual* (*AIM*) lists four levels of icing severity for use by pilots when reporting icing conditions. The *AIM* provides the following definitions of the levels, which subjectively relate the amount of ice that forms, the rate of ice accretion and the effect of the ice-protection system in removing the ice:

- "Trace: Ice becomes perceptible. Rate of accumulation slightly greater than sublimation. Deicing/anti-icing equipment is not utilized unless encountered for an extended period of time (over one hour);

- "Light: The rate of accumulation may create a problem if flight is prolonged in this environment (over one hour). Occasional use of deicing/anti-icing equipment removes/prevents accumulation. It does not present a problem if the deicing/anti-icing equipment is used;

- "Moderate: The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or flight diversion is necessary; [and,]

- "Severe: The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate flight diversion is necessary."

A common misperception is that the terminology also indicates the aerodynamic effects on the airplane. It does not. In some events, relatively small amounts of ice can affect an airplane far more adversely than large amounts of ice.

Ice Effects Vary

Ice can reduce the thrust produced by a propeller or fan, reduce the stall AOA, increase drag, cause buffet or vibration and result in changes to control in the pitch axis, roll axis or yaw axis. Ice also can cause uncommanded deflection of unpowered control surfaces or reduce the effectiveness of powered ("boosted") controls.

The icing-severity index in Table 1 (page 10) was developed by the author to illustrate factors that pilots should consider to gauge the severity of ice by its *effects on the airplane*. The effects vary, and the icing-severity index is based on a compilation of data from several turboprop airplane accidents and incidents. The data do not apply to all airplane types.

Note that stall AOA may change with no apparent visual cue, tactile cue or performance cue associated with the icing condition. Note, too, that airplanes that normally exhibit pre-stall buffet may exhibit *less* buffet in some icing conditions.[20]

Vigilance and appropriate response are the keys to ensure that an icing encounter characterized by one icing-severity-index level does not progress to a more severe level. Progression of severity can be rapid. For example, a pilot of a jet transport airplane reported that about one minute after encountering icing conditions during final approach, he had to increase power to maximum to maintain the appropriate airspeed and to track the glideslope. Incident reports have documented airspeed losses in excess of 60 knots in less than three minutes from the time of entry into icing conditions to the time of airplane upset.

The point is: Use the boots.

Table 1
Icing-severity Index

	Effect on Airplane				
Level	**Airspeed Reduction**	**Power Increase to Regain Airspeed**[1]	**Climb-rate Reduction**	**Control**	**Vibration or Buffet**[2]
Level 1	< 10 knots	< 10%	< 10%	No effect	No effect
Level 2	10–19 knots	10–19%	10–19%	No effect	No effect
Level 3	20–39 knots	20–39%	≥ 20%	Slow or overly sensitive response; stiff control feel or uncommanded deflection	Slight vibration in airframe or controls
Level 4	≥ 40 knots	Unable to maintain airspeed	Unable to climb	Limited or no response	Intense

1. When power required to regain airspeed increases beyond 50 percent in a twin-engine airplane, the flight condition likely cannot be maintained with one engine inoperative.
2. Not related to asymmetric accumulation of ice on the propellers; vibration caused by this condition can be detected by periodic changes in propeller speed accompanied by shedding of ice.

Source: John P. Dow Sr.

The pilot should consider the most severe effect of icing — whether airspeed reduction, the power increase required to regain the required airspeed, climb-rate reduction, control response or vibration/buffet — as the determining factor for his or her action. For example, if neither airspeed nor power is affected in level flight but the controls tend to self-deflect and higher-than-normal force is required to prevent self-deflection, that is a Level 3 condition as defined in Table 1, and appropriate action should be taken. (Thus, periodic assessment of control feel and response while hand flying the airplane is required in icing conditions.)

In the following discussion of the icing-severity index in Table 1, normal operation of the airplane's ice-protection system is assumed:

- In a Level 1 icing encounter, the performance decrements observed after normal operation of the ice-protection system indicate that ice has not been removed, or cannot be removed, from some surfaces of the airplane. If the airplane has a chemical ice-protection system, the system may not have been activated soon enough to provide adequate protection. Ice might be forming aft of protected surfaces or forming on unprotected areas. Various amounts of residual ice may remain on the boots during subsequent cycles. Increased vigilance is required, and options to exit the icing conditions should be evaluated;

- A Level 2 icing encounter may be problematic for some airplanes, and exiting the icing condition should be a priority. Exit strategy should be evaluated and initiated promptly. Climbing above icing conditions may not be practical. Maintaining airspeed at or above the manufacturer's published minimum airspeed for operation in icing conditions is important. In several ice-related accidents and incidents, loss of control occurred when airspeed was reduced or airplane configuration was changed for landing;

- A Level 3 encounter warrants emergency action. Because of possible flight-control degradation, the airplane should be hand flown; and,

- In a Level 4 encounter, performance and/or control have been compromised to the point where loss of control should be considered imminent. Control displacement and the rate of control application required for maneuvering should be limited. Turbulence or a change in airplane configuration may trigger a stall or an upset. Airspeed must not be allowed to decrease. An off-airport landing might be the only viable alternative for survival.

On Dec. 28, 1996, a pilot with relatively low time in type (Raytheon Beech King Air C90) was conducting an instrument landing system (ILS) approach to Rhinelander–Oneida County (Wisconsin, U.S.) Airport in icing conditions apparently conducive to a Level 4 encounter, as defined in Table 1 (freezing precipitation was observed in the area). As the airplane neared the airport, increased power was required to track the glideslope. The pilot detected signs of an impending uncommanded roll and opted not to allow airspeed to decrease further; he maintained control of the airplane, which struck the ground in a near-normal landing attitude. The airplane was destroyed, but none of the 10 occupants was seriously injured. The NTSB report said that the probable causes of the accident were the pilot's "inadequate weather evaluation and continued flight into forecast severe icing conditions which exceeded the capability of the airplane's anti-ice/deice system."

Identifying Killer Ice

European certification standards and U.S. certification standards for ice protection of transport category airplanes do not address icing caused by supercooled large droplets (SLDs) in freezing precipitation. SLDs impinge aft of protected surfaces and form ice that cannot be removed during flight in freezing temperatures (see photo right).

SLDs can result in various ice accumulations, including distributed roughness (i.e., individual ice elements distributed on the airfoil surface that do not touch each other and cannot be removed effectively; see photo, page 12), rough layers and ridges. During icing-research flights in instrumented airplanes, distributed roughness with element size and spacing equivalent to 20-grit sandpaper resulted in severe aerodynamic effects.

Signs of SLD conditions include ice forming aft of normal ice accretions as observed on windshields, propeller spinners and engine nacelles. In certain lighting conditions, the large droplets may be observed splashing and freezing immediately on windshields. This would be a further indication of a Level 3 condition, as defined in Table 1.

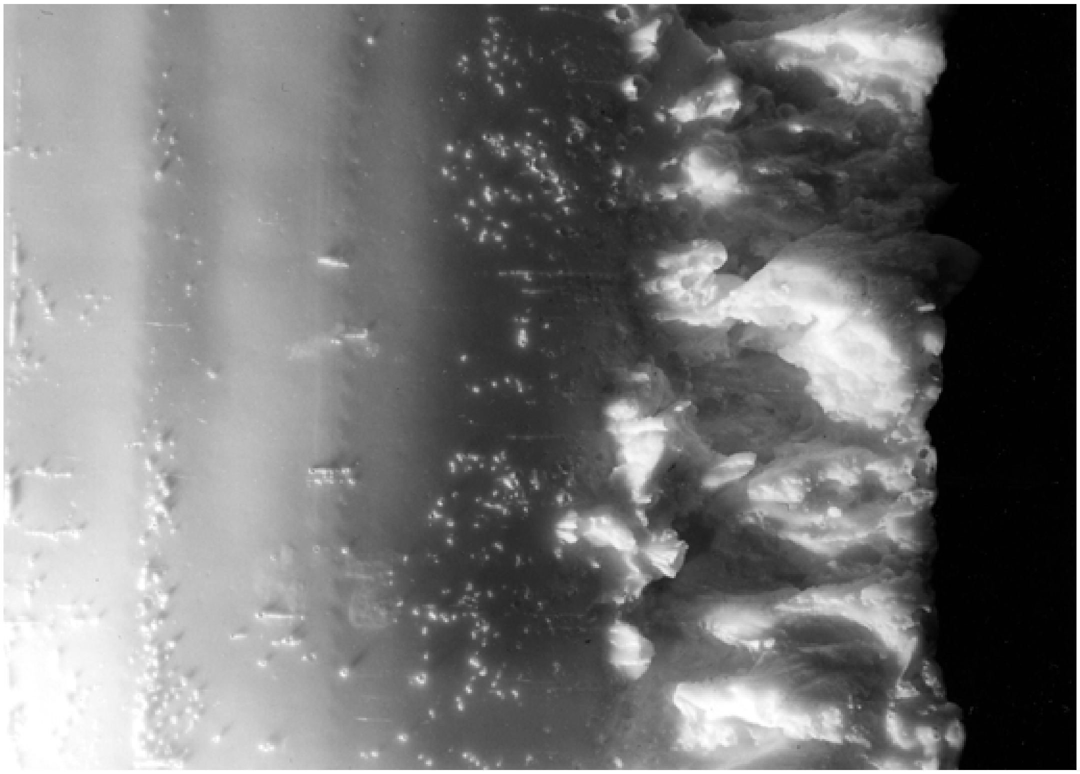
Ice accumulated on unprotected areas of an Avions de Transport Regional ATR 72 during an icing test flight. The airplane was flown behind a tanker to simulate an encounter with supercooled large droplets. (Photo: John P. Dow Sr.)

Spoiling the Balance

A tailplane stall (tail stall) is an "aerodynamic divergence" that reduces the balancing force from the tail — that is, the "negative" (downward) lift that contributes to longitudinal stability. A tail stall results in increased nose-down pitch, which increases the negative AOA of the tail and thus exacerbates the tail stall.

The airplane is most susceptible to a tail stall during approach, when there is limited altitude to recover. Corrective actions for a tail stall are exactly the opposite of those for a wing stall — for example, nose-*up* pitch must be applied. Taking corrective actions appropriate for a wing stall when the tail has stalled will exacerbate the tail stall; similarly, taking corrective actions for a tail stall when the wing has stalled will exacerbate the wing stall.

When flaps are extended beyond the approach setting, the tail-stall AOA is reduced. Also, when



During tests conducted in the U.S. National Aeronautics and Space Administration's icing-research tunnel, scattered small accumulations of ice, called distributed roughness, formed behind the much larger ice shape on the leading edge. The airfoil section was placed vertically in the tunnel, with the water-saturated airflow moving from right to left in this image. Distributed roughness can cause adverse effects disproportionate to its thickness.

(Photo: John P. Dow Sr.)

speed is increased, wing AOA is reduced but the tail's negative AOA increases, bringing it closer to stall AOA. Figure 2 (page 13) shows how increased airspeed changes the C_L of the wing and the C_L of the tailplane of an example turboprop airplane in landing configuration.

A longstanding rule of thumb about flying an approach with ice on the airplane is to increase airspeed. With ice on the tail, however, increasing speed, combined with flap extension and the nose-down control input, can trigger a tail stall. Maintaining speed below the manufacturer's recommended maximum speed for the configuration is important.

No turboprop airplane studied during the FAA Ice Contaminated Tailplane Stall Program in 1991 to 1994 was found to be susceptible to ice-related tailplane stall in normal service with the flaps extended to the first increment. In the brief time interval required for stall recovery using the procedure recommended here, ice is not likely to accumulate aft of the protected area of the upper wing surface with the flaps extended. Nevertheless, protracted flight in icing conditions with the flaps extended might result in ice accumulating aft of the ice-protection surfaces on the wing and tail.

Other factors that can contribute to a tail stall include gusts, nose-down pitch inputs and conducting a sideslip with the flaps extended.

Wing Stall or Tail Stall?

The following are general guidelines about identifying and responding to a tail stall:

- If the wings begin rocking at higher AOAs (lower airspeeds), the cause is not a tail stall; the cause is a loss of wing lift;
- There may be elevator buffet or some elevator "pumping" (oscillation of the control column) during the development of a wing stall or as the result of uncleared ice on the wing root; this does not indicate a tail stall;
- An important cue to the onset of tail stall when hand flying the airplane is the requirement for noticeably larger fore-and-aft control-column inputs, especially when lowering the flaps. Sloppy or spongy longitudinal control was very noticeable during tailplane-stall research conducted by NASA in a de Havilland Twin Otter; applying power

and applying nose-down inputs were shown to be potentially fatal;

- A tail stall is best characterized by diverging negative load factor. That means progressively feeling “lighter in the seat” as the stall develops;
- Retracting the flaps one notch immediately and resisting any uncommanded nose-down deflection (self-deflection) of the control column (unpowered flight controls) is recommended if any of the following occurs when the flaps are extended beyond the first setting:
  - A further increase in airspeed while at a higher-than-normal approach speed;
  - A nose-down control-column movement when flaps are extended further; or,
  - A forward control-column movement or a nose-down pitch change when the power setting is changed; and,
- A forward center of gravity (CG) is generally more conducive to a tail stall than an aft CG.

Training, Review Remain Essential

Training for flight in icing conditions should include the applicable information provided by the airplane manufacturer about critical airplane surfaces (e.g., upper surface of wing, lower surface of horizontal stabilizer, engine inlets, etc.) and for use of systems, flight controls, autopilot, power, configuration and airspeeds for each flight phase.

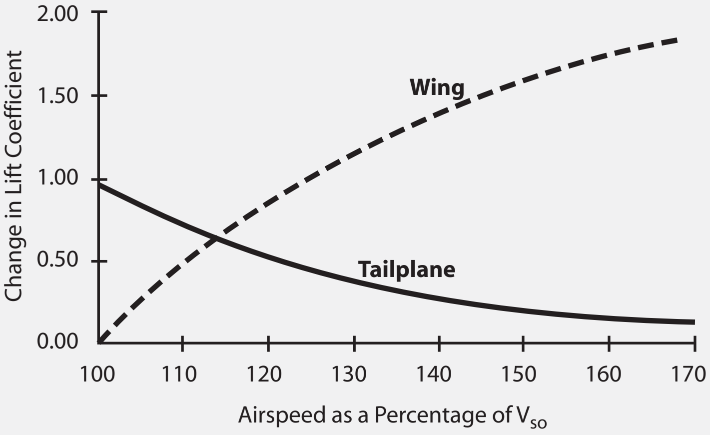
The following also should be included in training and reviewed periodically:

- Preflight deicing warrants the pilot-in-command’s attention. All ice and frost should be removed prior to flight by using heated hangars and/or deicing/anti-icing fluids. A tactile inspection for ice should be conducted by moving a bare hand or a thinly gloved hand over the critical surfaces. If there is ice, no matter how thin, it should be removed. The margin between the normal operating speed and the stall speed during takeoff may be less than the margin during approach; the margin may vary from 15 percent to 20 percent on takeoff, to 30 percent on landing. Even a minuscule amount of ice on the wing can erode that margin. In 1939, Jerome Lederer, founder of Flight Safety Foundation, said, “Strange as it may seem, a very light coating of snow or ice, light enough to be hardly visible, will have a tremendous effect on reducing the performance of a modern airplane.”

  Unless the airplane manufacturer provides specific instructions about where and how to polish frost, takeoff with polished frost is not allowed. FAA Advisory Circular 135-17, *Small Aircraft Ground Deicing*, says, “FAR [U.S. Federal Aviation Regulations Part] 135 and other rules for small aircraft allow takeoff with frost formations on the wing surfaces if the frost is polished smooth, thereby reducing the amount of surface roughness. It is recommended that all wing frost be removed by means of conventional deicing process; however, if polishing of frost is desired, the aircraft manufacturers’ recommended procedures should be followed”;[21]
- Icing certification does not imply or provide protection against all icing conditions; icing

Figure 2

Typical Effect of Airspeed on Turboprop Airplane Wing and Tailplane Lift Coefficient



V_{so} = Stall speed or minimum steady flight speed in landing configuration

Source: John P. Dow Sr.

certification also assumes no ice on the airplane during takeoff. Appendix C of FARs Part 25 and European Joint Aviation Requirements Part 25, which defines the certification icing conditions for transport category airplanes and small airplanes, does not cover all icing conditions. Icing certification does not imply any protection in freezing drizzle or freezing rain. Freezing precipitation can overwhelm ice-protection systems. Ice-protection systems for turboprop airplanes should be considered an aid to safely exit icing conditions;

Freezing precipitation can overwhelm ice-protection systems.

- In one day of widespread icing conditions, the airplanes operated by a large airline typically will fly more miles in icing conditions than all of the instrumented flights that were conducted to create and to verify the "icing-certification envelope" in Appendix C. There is an infinite variety of icing conditions;

- The airplane, through its response to an icing condition, may provide the pilot with some cues in advance — usually, reduced performance, vibration or buffet, or changes to control response and feel. The airplane will not communicate to the pilot an increase of stall speed (reduction of stall AOA) until that speed/AOA is reached;

- Airplane manufacturers use many tools to demonstrate compliance with icing certification regulations, including ice-shape prediction codes and artificial ice shapes, icing tunnels and flights in natural icing conditions, typically at temperatures colder than approximately minus 5 degrees C. There is no specific requirement to explore icing conditions at temperatures near freezing;

- There are no ice-shape prediction codes that can predict accurately the attributes of all ice formations, especially large shapes near freezing, runback ice, distributed roughness and the effects of droplet splashing and related phenomena;

- The important attributes of ice are location, shape, thickness and texture. Less important are the nuances associated with characterizing ice as rime, clear or mixed;

- Distributed roughness equivalent to 20-grit sandpaper and covering only approximately 15 percent to 20 percent of the airplane surface area can be far more adverse to airplane handling and performance than a large ice shape. Distributed roughness is not effectively shed with mechanical ice-protection systems;

- When there is insufficient thrust to maintain minimum airspeed *and* altitude, airspeed should be maintained. An off-airport landing with control is preferable to an uncontrolled descent;

- In documented incidents, large transport jet airplanes have had nearly a 100 percent drag increase in little more than a minute in rare, extreme icing situations, but had adequate thrust to maintain level flight. Turboprop airplanes and piston-engine airplanes typically have less excess thrust;

- Ice-induced airplane upsets usually occur in IMC. During flight in cruise configuration, if an uncommanded roll occurs or an uncommanded pitch-down occurs, the pilot immediately should reduce AOA. Flaps should be extended to the approach setting to increase lift, especially if ground contact is a concern. Discipline resulting from training will be required to push the nose down;

- Large transport jet airplanes have been involved in stalls during takeoff — and consequent fatal accidents — resulting from relatively thin ice or frost that was not removed from airfoils prior to flight. Airplanes with smaller-chord airfoils will be affected more adversely by a similar thickness of ice;

- When flown in the same icing condition, smaller-chord airfoils with smaller leading-edge radii will collect more ice than larger-chord airfoils with larger leading-edge radii;[22]

- Icing clouds are not always homogeneous; different icing conditions can be experienced at different altitudes or with different directions of flight. Pilot reports are helpful, but they should not be taken as ironclad indications of what other pilots will encounter;

- Airframe ice may accrete in total air temperatures or indicated air temperatures above zero degrees C, and in static air temperature below zero degrees C. Engine ice can accrete at static temperatures above zero degrees C; and,

- Adherence to the airplane manufacturer's limitations, guidance and instructions is paramount.

Periodic review of the stall-recovery procedure for turboprop airplanes in icing conditions — to apply nose-down pitch control and level the wings while increasing power, and to extend flaps to the first setting if necessary — will improve flight safety.■

[Contributing to the research and preparation of this report were: Gilbert Defer, former vice president of flight test for Avions de Transport Regional (ATR) and former flight test pilot for ATR, Airbus and Concorde; Jon Hannan, a former flight test pilot for the U.S. Federal Aviation Administration Small Airplane Directorate who has flown more than 250 types of aircraft; C.P. (Pete) Hellsten, former aerodynamicist and hydrodynamicist at Grumman Aerospace and professor at Embry-Riddle Aeronautical University and Georgia Tech; and Glenn Leonard, vice president of Cavok International.]

About the Author

John P. Dow Sr. is a consultant in aircraft certification and icing. Dow has more than 15 years of experience in airplane icing issues relating to airplane certification and accident investigation, and was the senior icing specialist for the U.S. Federal Aviation Administration (FAA), where he managed the FAA Tailplane Stall Program and was co-manager of the FAA Roll Upset Program. He was a member of the Ice Protection Harmonization Working Group, the Icing Certification Steering Group and the SAE Aircraft Environmental Systems Committee Aircraft Icing Subcommittee. He has participated in field investigations with the U.S. National Transportation Safety Board and has consulted with FAA's Office of Accident Investigation on many accidents related to icing conditions.

Dow has lectured on icing certification and accident investigation related to icing, written several papers on icing and sponsored U.S. National Aeronautics and Space Administration research on ice-induced tailplane stall. He holds a commercial pilot certificate.

Notes

1. The *Airplane Upset Recovery Training Aid*, completed in May 1998, was developed by 30 organizations — including Flight Safety Foundation, manufacturers, international air carriers, pilot organizations, flight-training organizations and government and regulatory agencies — primarily to reduce loss-of-control accidents caused by upsets of swept-wing airplanes. The training aid includes about 160 pages of text and two videotapes.

2. The Joint Aviation Authorities (JAA) said that the JAA Safety Strategy Initiative was established in 1998 "to support the JAA in meeting [its] commitment to improve safety in Europe in particular and worldwide in general." <www.jaa.nl> April 19, 2005.

3. The U.S. Federal Aviation Administration (FAA) said that the Commercial Aviation Safety Team (CAST) is "one element of the FAA's *Safer Skies* initiative to achieve significant reductions in fatal accidents by 2007. Established in 1997, the mission of CAST is to develop and focus implementation of an integrated, data-driven strategy to improve aviation safety leading to an 80 percent reduction in fatal accidents in the United States by 2007." <www.faa.gov> April 19, 2005.

4. U.K. Civil Aviation Authority Civil Aviation Publication 479, *World Airline Accident Summary*, Volume 2, said that during a scheduled passenger flight operated by Aero Transporti Italiani on Oct. 15, 1987, an Avions de Transport Regional ATR 42 was being flown on autopilot with the airspeed-hold mode selected to maintain a constant-speed climb at 133 knots. Icing conditions were forecast, and the flight crew observed ice accumulating on the airplane. At Flight Level 160 (approximately 16,000 feet), the airplane rolled 41 degrees right, 100 degrees left, 105 degrees right and 135 degrees left. The report said that during the attempted recovery, "three anomalous pitch-trim movements (until full-down) … prevented recovery." The airplane was destroyed when it struck Mount Crezzo, Italy. The three crewmembers and 34 passengers were killed.

   An independent analysis of the Crezzo accident by Rudolf Kapustin, president of Intercontinental Aviation Safety Consultants and a former investigator-in-charge for the U.S. National Transportation Safety Board (NTSB), said that a minimum airspeed of 145 knots was required for operating the ATR 42 in icing conditions and that the accident airplane encountered "locally extreme severe icing conditions." The crew disconnected the autopilot when the airplane rolled right. "A subsequent period of about 40 seconds marks the onset of a sequence of significant events which culminate in a series of stalls, aural stall warnings, stick-pusher activations, momentary recovery from stalls followed by re-entry into stalls, continued elevator nose-up inputs by the captain (contrary to a request by the copilot [the pilot flying]), three nose-down pitch-trim activations, a progressive increase in airspeed to V_{MO} [maximum operating airspeed] + 130 (380 knots), vertical speeds of up to –26,500 feet per minute and pitch attitudes of up to –65 degrees," Kapustin said. "Throughout the sequences of events, which resulted in an irreversible loss of control, the captain apparently *never* recognized the airplane's entry into a stall, or if he did, stall-recovery procedures were not initiated. The pitch trim was activated, most likely involuntarily, three times by the pilots; the first such action brought the airplane out of the stall, while the second and third brought the pitch trim to the maximum nose-down position, resulting in the pilot's perception that the controls were 'jammed.'"

5. NTSB Aircraft Accident Report AAR-96/01: *In-flight Icing Encounter and Loss of Control; Simmons Airlines, d.b.a. American Eagle Flight 4184; Avions de Transport Regional (ATR) Model 72-212, N401AM; Roselawn, Indiana; October 31, 1994*. The report said that the ATR 72 was being descended in a holding pattern to 8,000 feet when an uncommanded roll excursion occurred, followed by a rapid descent. The airplane was destroyed when it struck terrain. The four crewmembers and 64 passengers were killed. In an amendment to the final report, NTSB said that the probable causes of the accident were "the loss of control, attributed to a sudden and unexpected aileron-hinge-moment reversal that occurred after a ridge of ice accreted beyond the deice boots while the airplane was in a holding pattern during which it intermittently encountered supercooled cloud and drizzle/rain drops, the size and water content of which exceeded those described in the icing certification envelope. The airplane was susceptible to this loss of control, and the crew was unable to recover. Contributing to the accident were: 1) the French Directorate General for Civil Aviation's (DGAC's) inadequate oversight of the ATR 42 and [ATR] 72, and its failure to take the necessary corrective action to ensure continued airworthiness in icing conditions; 2) the DGAC's failure to provide the FAA with timely airworthiness information developed from previous ATR incidents and accidents in icing conditions; 3) the [FAA's] failure to ensure that aircraft icing certification requirements, operational requirements for flight into icing conditions and FAA-published aircraft icing information adequately accounted for the hazards that can result from flight in freezing rain; 4) the FAA's inadequate oversight of the ATR 42 and [ATR] 72 to ensure continued airworthiness in icing conditions; and 5) ATR's inadequate response to the continued occurrence of ATR 42 icing/roll upsets which, in conjunction with information learned about aileron control difficulties during the certification and development of the ATR 42 and [ATR] 72, should have prompted additional research and the creation of updated airplane flight manuals, flight crew operating manuals and training programs related to operation of the ATR 42 and [ATR] 72 in such icing conditions."

6. NTSB Aircraft Accident Report AAR-98/04: *In-flight Icing Encounter and Uncontrolled Collision With Terrain; Comair Flight 3272; Embraer EMB-120RT, N265CA; Monroe, Michigan; January 9, 1997*. The report said that the airplane struck terrain during a rapid descent after an uncommanded roll excursion. The airplane was destroyed. The three crewmembers and 26 passengers were killed. NTSB said that the probable cause of the accident was "the [FAA's] failure to establish adequate aircraft certification standards for flight in icing conditions, the FAA's failure to ensure that a Centro Tecnico Aeroespacial/FAA-approved procedure for the accident airplane's deice system operation was implemented by U.S.-based air carriers, and the FAA's failure to require the establishment of adequate minimum airspeeds for icing conditions, which led to the loss of control when the airplane accumulated a thin, rough accretion of ice on its lifting surfaces. Contributing to the accident were the flight crew's decision to operate in icing conditions near the lower margin of the operating airspeed envelope (with flaps retracted) and Comair's failure to establish and adequately disseminate unambiguous minimum airspeed values for flap configurations and for flight in icing conditions."

7. Gawron, Valerie J.; Berman, Benjamin A.; Dismukes, R. Key; Peer, Jeffrey H. "New Airline Pilots May Not Receive Sufficient Training to Cope With Airplane Upsets." *Flight Safety Digest* Volume 22 (July–August 2003).

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17. Hashmi, Tasneem; director of training, FlightSafety International Toronto (Canada) Learning Center. Telephone interview by Lacagnina, Mark. Alexandria, Virginia, U.S. April 18, 2005. Flight Safety Foundation, Alexandria, Virginia, U.S.
18. NTSB accident report no. CHI93MA061. The report said that the airplane's right main landing gear broke, the fuel tank ruptured and the rear spar in the right wing bent upward during the hard landing. None of the 31 occupants was injured. NTSB said that the probable cause of the accident was "the first officer's failure to maintain a proper descent rate during the landing and the captain's inadequate supervision by not taking timely action to ensure a safe landing."
19. Ohio Aerospace Institute Ice Bridging Conference. Cleveland, Ohio, U.S. 1997.
20. Information about this phenomenon was included in the FAA report: *Mitsubishi Heavy Industries MU-2 Series Airplane Special Certification Review*. June 27, 1997.
21. U.S. Federal Aviation Regulations Part 91.527 and Part 135.227 permit takeoff with frost adhering to an airplane's wings, stabilizing surfaces or control surfaces if the frost has been "polished to make it smooth." FAA Advisory Circular 20-117, *Hazards Following Ground Deicing and Ground Operations in Conditions Conducive to Aircraft Icing*, says, "If ice formations are present, other than those considered in the certification process, the airworthiness of the aircraft may be invalid and no attempt should be made to fly the aircraft until it has been restored to the clean configuration. The ultimate responsibility for this determination rests with the pilot-in-command of the aircraft."
22. Perkins, Porter J.; Rieke, William J. *In-flight Icing*. Batavia, Ohio, U.S.: Sporty's Pilot Shop.

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No Fatal Accidents Disrupted Australian Regular Public Transport, Charter Operations in 2004

Accident rates for regular public transport and fatal-accident rates for charter operations have trended lower over a multi-year period. No comparable trend, however, can be seen in fatal-accident rates for private/business operations.

— FSF EDITORIAL STAFF

In 2004, Australian aircraft in regular public transport[1] (RPT) operations and charter[2] operations were involved in no fatal accidents, the first year without a charter-operation fatal accident in the 1995–2004 period. The accident rate per 100,000 flight hours for multi-engine airplanes declined for both high-capacity[3] airplanes and low-capacity[4] airplanes in 2003, the latest year for which data are available, compared with 2002. The fatal-accident rates for private/business[5] airplanes and helicopters increased in 2003 compared with the previous year.

The data, from the Australian Transport Safety Bureau (ATSB), showed that there were no accidents in high-capacity RPT in 2004. There had been 12 accidents during the previous nine years (Table 1, page 19). There was one low-capacity RPT accident in 2004, compared with an annual range of zero accidents to four accidents in the previous nine years. (All data in this article are for occurrences within Australian territory.)

The 16 accidents in charter operations in 2004 compared with 25 in 2003 and with an annual average of 31.6 in the previous nine years. In private/business operations, the numbers of accidents (63) and fatal accidents (six) represented increases from 2003, but were lower than the annual averages for the previous nine years of 76.6 accidents and 9.4 fatal accidents.

In terms of aircraft types (Table 2, page 20), accidents decreased in 2004 compared with the previous year for multi-engine airplanes and increased for single-engine helicopters. There was one accident involving a multi-engine helicopter in 2004 and none in 2003.

The three fatal accidents in 2004 involving multi-engine airplanes compared with an annual range

Table 1
Accidents, Fatal Accidents and Fatalities, Australian-registered Civil Aircraft, in Australia, 1995–2004

Type of Operation	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
High-capacity regular public transport											
Accidents	0	0	0	1	5	1	3	1	1	0	12
Fatal accidents	0	0	0	0	0	0	0	0	0	0	0
Fatalities	0	0	0	0	0	0	0	0	0	0	0
Low-capacity regular public transport											
Accidents	4	2	0	2	3	3	3	4	3	1	25
Fatal Accidents	1	0	0	0	0	1	0	0	0	0	2
Fatalities	2	0	0	0	0	8	0	0	0	0	10
Charter											
Accidents	40	33	48	41	21	26	31	19	25	16	300
Fatal Accidents	3	6	4	2	3	3	4	3	2	0	30
Fatalities	8	13	8	7	10	11	10	8	8	0	83
Private/Business											
Accidents	90	83	74	90	72	78	83	69	50	63	752
Fatal Accidents	12	9	7	16	16	8	10	4	3	6	91
Fatalities	20	21	12	33	27	9	19	10	8	15	174
Totals											
Accidents	134	118	122	134	101	108	120	93	79	80	1,089
Fatal Accidents	16	15	11	18	19	12	14	7	5	6	123
Fatalities	30	34	20	40	37	28	29	18	16	15	267

Note: The two fatalities recorded for low-capacity regular public transport in 1995 were the result of a training accident; the aircraft was not operating in public service.

The fatalities for 2001 in the private/business sector included one ground fatality.

Regular public transport is defined as scheduled air service available for the transport of members of the public, or for use by members of the public for the transport of cargo (freight and/or mail), for hire or reward.

High capacity is defined as aircraft with a seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,260 pounds).

Low capacity is defined as aircraft with a seating capacity of fewer than 39 seats or a maximum payload not exceeding 4,200 kilograms.

Charter is defined as carriage of cargo or passengers on nonscheduled operations by the aircraft owner or the owner's employees for hire or reward. Private is defined as flying for private pleasure, sport or recreation, including parachute dropping. Business is defined as flying by the aircraft owner, the owner's employees or the hirer of the aircraft for business or professional reasons, but not directly for hire or reward.

Source: Australian Transport Safety Bureau

of zero accidents to four accidents in the previous nine years. For single-engine helicopters, the four fatal accidents in 2004 were in the middle of an annual range of two accidents to seven accidents in the previous nine years. Data showed a 10th consecutive year with no fatal accidents involving multi-engine helicopters.

For multi-engine airplanes involved in high-capacity RPT during the 1993–2003 period (Table 3, page 20), the 2003 rate of 0.14 accidents per 100,000 flight hours was about half the annual average rate of 0.28 for the previous 10 years. In the corresponding low-capacity category, the 2003 rate of 1.45 accidents per 100,000 flight hours compared with an annual average for the previous 10 years of 1.26.

For the second successive year, the fatal-accident rate for multi-engine airplanes in charter operations had a rate of zero per 100,000 flight hours in 2003 (Table 4, page 21). Single-engine helicopters in charter operations had 1.51 fatal accidents per 100,000 flight hours, following three successive years of a zero rate.

Multi-engine airplanes in private/business operations had 1.91 fatal accidents per 100,000 flight hours in 2003, the highest rate since 1993. The corresponding 2003

Table 2
Accidents, Fatal Accidents and Fatalities, Australian-registered Civil Aircraft, in Australia, 1995–2004

Type of Aircraft	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Total
Multi-engine airplane											
Accidents	40	37	34	41	25	33	33	25	31	13	312
Fatal accidents	4	4	1	2	1	3	4	0	4	3	26
Fatalities	10	8	1	3	3	17	14	0	10	9	75
Single-engine helicopter											
Accidents	31	33	42	35	28	45	38	23	29	36	340
Fatal accidents	7	6	4	5	6	3	4	2	6	4	47
Fatalities	9	8	5	6	8	8	5	5	14	6	74
Multi-engine helicopter											
Accidents	0	1	3	0	0	1	2	0	0	1	8
Fatal accidents	0	0	0	0	0	0	0	0	0	0	0
Fatalities	0	0	0	0	0	0	0	0	0	0	0
Totals											
Accidents	71	71	79	76	53	79	73	48	60	50	660
Fatal accidents	11	10	5	7	7	6	8	2	10	7	73
Fatalities	19	16	6	9	11	25	19	5	24	15	149

Source: Australian Transport Safety Bureau

Table 3
Multi-engine Airplane Accident and Fatality Rates, Australian Regular Public Transport, in Australia, 1993–2003

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Average
Accidents per 100,000 flight hours												
High-capacity airplanes	0.28	0.25	0.00	0.00	0.00	0.22	1.07	0.20	0.59	0.22	0.14	0.27
Low-capacity airplanes	2.60	1.40	1.83	0.84	0.00	0.70	1.06	1.06	1.21	1.94	1.45	1.28
Fatal Accidents per 100,000 flight hours												
High-capacity airplanes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Low-capacity airplanes	0.52	0.00	0.46	0.00	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.12
Fatalities per 100,000 flight hours												
High-capacity airplanes	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Low-capacity airplanes	3.64	0.00	0.91	0.00	0.00	0.00	0.00	2.82	0.00	0.00	0.00	0.67

Note: Regular public transport is defined as scheduled air service available for the transport of members of the public, or for use by members of the public for the transport of cargo (freight and/or mail), for hire or reward.

High capacity is defined as aircraft with a seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,260 pounds).

Low capacity is defined as aircraft with a seating capacity of fewer than 39 seats or a maximum payload not exceeding 4,200 kilograms.

Source: Australian Transport Safety Bureau

rate for single-engine helicopter private/business operations was 3.30.

Fatalities per 100,000 flight hours (Table 5, page 21) were zero in 2003 for the second consecutive year in multi-engine airplane charter operations. In single-engine helicopter charter operations, the fatality rate was 6.04 per 100,000 flight hours, the highest rate since 1993. Fatality rates for private/business operations also rose in 2003 for both airplanes and helicopters.

The data were published on the Internet at <www.atsb.gov.au/aviation>.■

Table 4

Fatal Accidents per 100,000 Flight Hours, Australian-registered Charter Aircraft and Private/Business Aircraft, in Australia, 1993–2003

Type of Operator	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Average
Charter												
Multi-engine airplanes	0.00	2.64	0.78	1.10	0.00	0.36	0.35	0.78	0.73	0.00	0.00	0.61
Single-engine helicopters	12.12	0.00	1.95	4.01	5.02	0.00	1.85	0.00	0.00	0.00	1.51	2.41
Private/business												
Multi-engine airplanes	2.70	1.63	1.67	1.39	1.55	1.57	0.00	0.00	1.90	0.00	1.91	1.30
Single-engine helicopters	16.04	6.84	15.81	0.00	0.00	12.17	22.93	4.55	0.00	0.00	3.30	7.42

Note: There were no fatal accidents involving multi-engine helicopters in these categories in the 1993–2003 period.

Charter is defined as carriage of cargo or passengers on nonscheduled operations by the aircraft owner or the owner's employees for hire or reward. Private is defined as flying for private pleasure, sport or recreation, including parachute dropping. Business is defined as flying by the aircraft owner, the owner's employees or the hirer of the aircraft for business or professional reasons, but not directly for hire or reward.

Source: Australian Transport Safety Bureau

Table 5

Fatalities per 100,000 Flight Hours, Australian-registered Charter Aircraft and Private/Business Aircraft, in Australia, 1993–2003

Type of Operator	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	Average
Charter												
Multi-engine airplanes	0.00	9.67	2.72	2.70	0.00	0.72	1.06	3.52	2.92	0.00	0.00	2.07
Single-engine helicopters	28.29	0.00	1.95	6.02	5.02	0.00	1.85	0.00	0.00	0.00	6.04	2.41
Private/business												
Multi-engine airplanes	9.43	6.51	1.67	2.78	1.55	1.57	0.00	0.00	3.80	0.00	9.54	3.35
Single-engine helicopters	24.06	13.69	23.72	0.00	0.00	12.17	28.66	9.11	0.00	0.00	6.59	7.42

Note: There were no fatal accidents involving multi-engine helicopters in these categories in the 1993–2003 period.

Charter is defined as carriage of cargo or passengers on nonscheduled operations by the aircraft owner or the owner's employees for hire or reward. Private is defined as flying for private pleasure, sport or recreation, including parachute dropping. Business is defined as flying by the aircraft owner, the owner's employees or the hirer of the aircraft for business or professional reasons, but not directly for hire or reward.

Source: Australian Transport Safety Bureau

Notes

1. Regular public transport includes all air-service operations in which aircraft are available for the transport of members of the public, or for use by members of the public, for the transport of cargo (freight and/or mail), for hire or reward and which are conducted in accordance with fixed schedules to and from fixed terminals over specific routes, with or without intermediate stopping places between terminals.
2. Charter operations involve carriage of cargo or passengers on nonscheduled operations by the aircraft owner or the owner's employees for hire or reward.
3. High-capacity operations involve aircraft with a seating capacity of more than 38 seats or a maximum payload of more than 4,200 kilograms (9,260 pounds).
4. Low-capacity operations involve aircraft with a seating capacity of fewer than 39 seats or a maximum payload not exceeding 4,200 kilograms.
5. Private operations and business operations are combined into a single private/business category for statistical purposes by the Australian Transport Safety Bureau. Private operations include flying for private pleasure, sport or recreation, including parachute dropping. Business operations include flying by the aircraft owner, the owner's employees or the hirer of the aircraft for business or professional reasons, but not directly for hire or reward.

'Socio-technical Failures' Called a Safety Threat

Models of human error derived from engineering and experimental psychology are inadequate to understand the complex interaction among technology, operators and organizational systems, the author says.

— FSF LIBRARY STAFF

Books

Ten Questions About Human Error: A New View of Human Factors and System Safety. Dekker, Sidney W.A. Mahwah, New Jersey, U.S.: Lawrence Erlbaum Associates, 2005. 219 pp. Figures, references, index.

"The once-pragmatic ideas of human factors and system safety are falling behind the practical problems that have started to emerge from today's world," says the author, a professor of human factors at Lund University, Sweden, whose work was supported by a grant from the Swedish Flight Safety Directorate. "We may be in for a repetition of the shifts that came with the technological developments of World War II, where behaviorism [the assumption in one school of psychology that only behavior, and not experience, could be studied scientifically] was shown to fall short. This time it may be the turn of human factors and system safety. Contemporary developments, however, are not just technical. They are socio-technical: Understanding what makes systems safe or brittle requires more than knowledge of the human-machine interface."

The author believes that further advances in risk reduction are hampered by mental models derived from engineering and experimental psychology, along with their associated vocabulary.

"This vocabulary, the subtle use of metaphors, images and ideas, is more and more at odds with the interpretative demands posed by modern organizational accidents," says the author. "The vocabulary expresses a world view (perhaps) appropriate for technical failures but incapable of embracing and penetrating the relevant areas of socio-technical failures — those failures that involve the intertwined efforts of technology and the organized social complexity surrounding its use. Which is to say, most failures today."

The author says that current human factors models and system-safety models are based on the ideas of failures (mechanical or human) and defenses against failures. The presumption is that small failures, which cause incidents, can lead if not corrected to large failures, which can cause accidents. So the search is on for "human errors, holes in layers of defense, latent problems, organizational deficiencies and resident pathogens."

But there is a more subtle and normally invisible class of safety threats, by which "apparently safe systems can drift into failure," the author says in the chapter titled "Why Do Safe Systems Fail?"

"Drifting into failure is incremental," he says. "Accidents do not happen suddenly, nor are they preceded by monumentally bad decisions or bizarrely huge steps away from the ruling norm."

According to what he calls the "banality of accidents" thesis, "The potential for having an accident grows as a normal by-product of doing normal business under normal pressures of resource scarcity and competition."

Conceptual Foundations of Human Factors Measurement. Meister, David. Mahwah, New Jersey, U.S.: Lawrence Erlbaum Associates, 2004. 260 pp. Figures, tables, references, index.

The author says that he is not satisfied with the *status quo* in human factors (HF) research. "Like most people, HF professionals want simple answers to complex problems," he says. "They forget that there may be unexplored depths underlying the most common practices they perform."

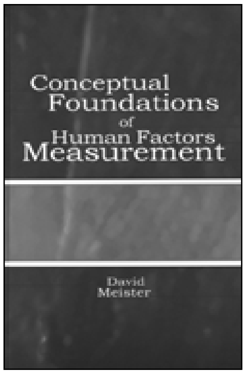
The study of HF has not changed as much throughout its history as is commonly assumed, the author believes.

"Without question, the advent of computers has made a good deal of difference to HF people, reflected in such advances as computerized devices for behavioral measurement, the development of human-performance models, increased emphasis on cognitive functions, and a concentration of interest in information and information management," he says. "On the other hand, the fundamental functions of measurement have remained much the same as they were in 1950 and even earlier. Still the focus of our research is on the experiment and the questions studied are tailored to satisfy experimental design requirements."

The author believes that measurement is fundamental to HF research, and much of the book explores its methods and uses.

Among the themes and assumptions that permeate the book, the author says, are the following:

- "Covert factors underlie human performance and customary measurement practices. One reason for HF research is to make these factors overt";
- "For progress to be made, it is necessary for every discipline to perform a continuing self-examination of its processes"; and,
- "HF as a discipline is influenced by socio-cultural as well as scientific factors."



Aviation Century: World War II. Dick, Ron; Patterson, Dan (photographer). Erin, Ontario, Canada: Boston Mills Press, 2004. 354 pp. Photographs (color and black-and-white), bibliography, index.

Aviation was becoming an important component of peacetime transportation when the world went to war in 1939. For the next six years, airplanes would become primarily weapons. Flight crewmembers killed and were killed.

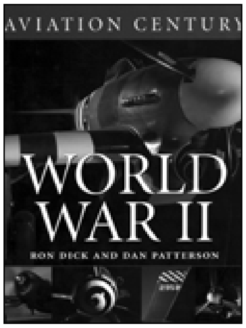
It was quickly evident that aviation would strongly influence the course of World War II. The battles of Coral Sea and Midway in the Pacific in 1942 were the first naval battles in history in which the opposing fleets never came within sight of one another; airplanes were used in all the attacks. From the Battle of Britain in 1940, credited with preventing a German invasion of Britain, to the Boeing B-29 raids on Tokyo, Hiroshima and Nagasaki that led to the Japanese surrender, the fates of people on land and sea were determined from the air.

"Aircraft turned the tide again and again," says retired Air Vice-Marshal Ron Dick, a pilot with the U.K. Royal Air Force for 38 years, in his introduction. "Their worth was proved in many roles besides bombing, including such varied tasks as air defense, close support of ground operations, interdiction [destroying an enemy's supply line], airborne assault, maritime patrol, shipping strikes, transport support and reconnaissance."

The book — part of the Aviation Century series — is divided into two sections, "Europe and the Middle East" and "The Pacific, China, Burma and India." Within each section chapters are devoted to campaigns such as "The Eastern Front," "Turning Point Midway" and "The Islands of the Pacific."

The author's text for each chapter explains the military aviation units involved, their leadership, the strategy, the airplanes flown and the results. The aviation operations of both sides in the conflict, the Allies and the Axis, are given more or less equal attention. The author includes in his survey aspects of World War II aviation that will be relatively unfamiliar to many readers, such as the roles played by the Soviet, Polish and Italian air forces.

Illustrations include both archival photographs and recent photographs by Dan Patterson. Patterson's



full-color photographs show surviving and reconstructed aircraft, in some cases with pilots who flew them; interior views of cockpits, bomb bays and gun turrets; engines; and assemblages of pilots' and crewmembers' equipment, including items such as flight jackets, headphones, goggles, oxygen masks, insignia, logbooks, survival equipment and flight manuals. Paintings, in addition to photographs of the time, illustrate aerial battles.

Report

Employee Attitudes Within the Air Traffic Organization. Hackworth, Carla A.; Cruz, Crystal E.; Jack, Dan G.; Goldman, Scott; King, S. Janine. U.S. Federal Aviation Administration (FAA) Office of Aerospace Medicine. DOT/FAA/AM-04/23. December 2004. 18 pp. Tables, appendix, references. Available on the Internet at <www.cami.jccbi.gov> or through NTIS.*

FAA says that in the past few years, as part of its efforts to improve safety, control operating costs, improve efficiency, increase customer satisfaction and improve services, it has changed its business practices by introducing a performance-based organization (PBO) in which accountability is linked with clear objectives, measurable performance goals and customer-service standards.

In November 2003, FAA reorganized air traffic employees into a PBO and named the new organization the Air Traffic Organization (ATO). The ATO was formed by merging 37,000 FAA employees into 10 air traffic service units, with five units providing support functions and five units providing operational functions.

Understanding that changes in an organization could create difficulties between employees and management, FAA surveyed employees to assess the influence of changes. Survey results were compared to results from previously administered job-satisfaction surveys. Survey items that corresponded to ATO management team core values — integrity and honesty, accountability and responsibility, commitment to excellence, commitment to people, and fiscal responsibility — were summarized for each ATO service unit.

The report says that "data illuminate areas that should be targeted for intervention through specific action plans and well-defined communication plans and provide a baseline for comparison to future EAS [employee attitude survey] administrations."

Regulatory Materials

Aeronautical Radio Station Operator's Guide. U.K. Civil Aviation Authority (CAA) Safety Regulation Group (SRG). Civil Aviation Paper (CAP) 452. Feb. 11, 2005. 12th edition. 24 pp. Appendixes, glossary, references. Available on the Internet at <www.caa.co.uk> or from Documedia.**

CAP 452 offers guidance for those who operate or wish to operate aeronautical radio stations used for airport air-ground communication, offshore communication service to helicopters or operational control communications with company-owned aircraft or company-operated aircraft.

The document is based on International Standards and Recommended Practices (SARPs) from relevant International Civil Aviation Organization (ICAO) annexes. The document says that the United Kingdom complies with the ICAO SARPs as far as is practicable and differs from the ICAO SARPs about experience required for an aeronautical station operator license.

For candidates pursuing an operator's certificate of competence, the CAP includes a syllabus with examination details attached.

CAP 452 is updated by amendments and revisions.

Mandatory Requirements for Airworthiness. U.K. Civil Aviation Authority (CAA) Safety Regulation Group (SRG). Civil Aviation Paper (CAP) 747. Jan. 31, 2005. 360 pp. Tables, appendixes. Available on the Internet at <www.caa.co.uk> or from Documedia.**

Formation of the European Aviation Safety Agency (EASA) and implementation of associated European legislation have caused changes in procedures and responsibilities for regulating continuing airworthiness for most civil aircraft registered in European Union states. Subsequently, the CAA says, it made substantial changes in its publications that relate to airworthiness and "declare[d] its intention to retain certain requirements for U.K.-registered aircraft."

Aircraft were classified into two groups — EASA and non-EASA — in accordance with European legislation. Consequently, mandatory airworthiness information for EASA aircraft and non-EASA aircraft are different. The CAA says that "certain classes of aircraft are excluded from EASA's jurisdiction and therefore remain subject to regulation under the national legislation of their States of Registry, as administered by the relevant National Aviation Authorities."

The CAP describes differences between these groups and identifies mandatory requirements applicable to EASA aircraft and to non-EASA aircraft.

Lists of aircraft, appliances and other products (e.g., engines, propellers and parts) that are subject to EASA airworthiness regulations are provided. Aircraft, appliances and other products that are identified as non-EASA and are subject to regulation of airworthiness at a national level are similarly identified. The CAA says that "in cases of doubt over the classification of a particular aircraft, clarification should be sought from the [U.K.] CAA."

This CAP provides a single point of reference for mandatory airworthiness directives (ADs) and other airworthiness information for U.K.-registered civil aircraft, and it is the primary means by which the CAA communicates continuing airworthiness requirements.

Compilation of CAP 747 caused some CAA requirements to be added or withdrawn and caused some regulatory publications to be cancelled, replaced or changed in status. Affected publications, CAPs and ADs are identified and explained in this paper.

Reporting Wildlife Aircraft Strikes. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 150/5200-32A. Dec. 22, 2004. Table. 44 pp. Available from FAA via the Internet at <www.airweb.faa.gov> or from the U.S. Department of Transportation (USDOT).***

As reported in the AC, "Worldwide, wildlife strikes cost civil aviation an estimated [US]$1.2 billion annually. Each year in the U.S., wildlife strikes to U.S. civil aircraft cause about [US]$500 million in damage to aircraft and about 500,000 hours of civil aircraft down time."

FAA programs and reporting procedures to address this safety issue are discussed. One program involves collecting information from reports and entering these data into FAA's searchable database, where wildlife data are analyzed for dissemination to the International Civil Aviation Organization (ICAO) and other aviation organizations.

The AC describes the different levels of access to the database, how to obtain access passwords and the types of strike information available. For example, the public has access to basic information, but an airport operator or airline operator may obtain access to records relevant to its specific concerns.

The definition of a wildlife strike, methods of reporting wildlife strikes and guidelines for collecting and submitting bird remains for species identification are provided.

Reporting is not limited to pilots. FAA says that it "actively encourages the voluntary reporting of wildlife strikes" by airport operations personnel, aircraft maintenance personnel, airframe and engine manufacturers, and anyone else having knowledge of a strike.

Use of Cockpit Displays of Digital Weather and Operational Information. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 00-63. Sept. 24, 2004. 8 pp. Glossary, references. Available from FAA via the Internet at <www.airweb.faa.gov> or from the U.S. Department of Transportation (USDOT).****

This AC provides guidance on the use of flight information services data link (FISDL) to aircraft flight crewmembers and others. Guidance in this AC applies to all operators using the FAA very-high-frequency (VHF) FISDL system and to those using non-FAA FISDL systems.

FISDL is a data-link service that provides aeronautical weather and operational data to augment pilot voice communication with flight service stations, air traffic control facilities and airline-operation control centers. FISDL does not replace voice communication between pilots and controllers or flight service specialists, or between pilots and aircraft dispatchers, for interpretation of weather and weather-related operational information, says the AC.

The AC says that FAA's VHF FISDL system displays cockpit information in text and graphic formats to enhance a pilot's situational awareness and improve pilot judgment and decision making.

The AC describes FAA's VHF FISDL system and non-FAA FISDL systems provided by commercial organizations with regard to information products (e.g., significant meteorological information or SIGMETs) and weather products (e.g., aviation routine weather reports or METARs).

Factors to consider in operational use of FISDL — types of systems, services offered by commercial providers, limitations of products, signal coverage, training programs and operator qualifications — are discussed.

Certification of Transport Category Airplanes for Flight in Icing Conditions. U.S. Federal Aviation Administration (FAA) Advisory Circular (AC) 25.1419-1A. May 7, 2004. References. 27 pp. Available from FAA via the Internet at <www.airweb.faa.gov> or from the U.S. Department of Transportation (USDOT).****

This AC provides guidance to airplane manufacturers, airplane modifiers, foreign regulatory authorities and FAA transport airplane type-certification engineers and their designees regarding certification of airframe ice-protection systems on transport category airplanes.

The information in this AC is not mandatory or regulatory. It describes acceptable means, but not the only means, for demonstrating compliance with applicable regulations, and it supplements similar guidance provided in other ACs about icing requirements for other airplane parts (engine, engine inlet, propeller, etc.).

This guidance AC applies to approval of the installation and operation of ice-protection systems in an icing environment as defined in U.S. Federal Aviation Regulations (FARs) Part 25, *Airworthiness Standards: Transport Category Airplanes*, Appendix C (continuous maximum icing and intermittent maximum icing). The AC says that "if certification for flight in icing conditions is desired, the airplane must be able to safely operate throughout the icing envelope of Appendix C."

Among the topics the AC discusses are the following:

- Certification plans;
- Analysis of areas to be protected (such as leading edges of control-surface balance areas) and components to be protected (such as antennas and masts);
- Testing (dry-air ground tests, as well as flight and simulation compliance tests);
- Performance levels of all basic airplane systems and components;
- The phenomenon of ice-contaminated tailplane stall; and,
- Information that should be included in an airplane flight manual (such as operating limitations of the ice-protection system).

The AC contains a list of related documents for supplemental research — FARs, FAA technical reports, FAA ACs and RTCA (formerly called the Radio Technical Commission for Aeronautics) guidance documents.

[This AC cancels AC 25.1419-1, *Certification of Transport Category Airplanes for Flight in Icing Conditions,* dated Aug. 18, 1999.] ■

Sources

* National Technical Information Service (NTIS)
5285 Port Royal Road
Springfield, VA 22161 U.S.
Internet: <www.ntis.gov>

** Documedia Solutions
37 Windsor St.
Cheltenham, Gloucester GL52 2DG U.K.
Internet: <www.documedia.co.uk>

*** U.S. Department of Transportation (USDOT)
800 Independence Ave. SW
Washington, DC 20591 U.S.

**** U.S. Department of Transportation (USDOT)
Subsequent Distribution Office
Ardmore East Business Center
3341 Q 75th Ave.
Landover, MD 20785 U.S.

B-767 Encounters Hail, Wind Shear During Takeoff

The report by the Australian Transport Safety Bureau said that neither weather forecasters nor air traffic controllers had a complete picture of the deteriorating weather conditions at the departure airport.

— FSF 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

Crew Did Not Receive Updated Weather Information

Boeing 767. Minor damage. No injuries.

After takeoff from an airport in Australia on a domestic flight, as the crew flew the airplane through 800 feet, they encountered heavy rain, hail and wind shear. The airplane descended about 130 feet, and the ground-proximity warning system (GPWS) sounded a "Don't Sink" alert. The crew increased power, in accordance with company procedures, and flew the airplane out of the wind shear.

After the incident, the cabin crew reported dents on the leading edges of the wings. The flight continued to the destination airport for a normal landing.

Records showed that at 1339 local time, when the flight crew requested taxi clearance, they told an air traffic controller that they had heard automatic terminal information service (ATIS) Echo, which had been issued at 1310 and which indicated no adverse weather conditions at the airport.

The Bureau of Meteorology (BOM) said that its weather forecasters "first became aware of the severity of the thunderstorm involved in the occurrence at about 1336."

At 1338, ATIS Foxtrot was issued, including information that visibility would be reduced to 5,000 meters (three statute miles) in rain and thunderstorms. Controllers in the airport air traffic control tower did not tell the crew about the new weather information. The crew received a takeoff clearance at 1345.

At 1346:49, they told air traffic control tower that they had stopped their turn to the assigned departure heading because of weather. Later, they told a controller that they had encountered heavy rain and hail during the departure.

The BOM said later that the thunderstorm had passed over the airport between 1340 and 1349.

The incident report said that the occurrence "involved a number of issues, including the limitations of airborne weather radar, the mutual exchange of information between BOM and air traffic control and provision of information to the B-767 crew."

The airplane's weather radar "did not have the capability to provide predictive forward-looking wind shear detection and avoidance information to the crew, nor was there a requirement for it to do so," the report said. The weather radar display showed areas of red, which indicated heavy rain, but did not indicate the presence of hail or other severe weather conditions.

Although BOM forecasters were aware of the severity of the thunderstorm and observed weather radar that showed the storm cell moving toward the airport and then passing overhead, they did not warn airport air traffic services (ATS), which issued ATIS information.

"ATS controllers could see that the thunderstorm was approaching and that weather conditions were deteriorating," the report said. "However, they did not contact BOM staff to ascertain the severity of the approaching weather. Consequently, neither BOM nor [airport] controllers had a complete picture of the deteriorating meteorological situation. In turn, the crew … was not provided with a complete picture of the meteorological situation."

After the incident, the operator amended procedures for distributing weather information to flight crews; an audio-visual presentation on the incident was produced for Airservices Australia and presented at an Airservices Australia/industry forum; an article about the incident was written for distribution to flight crews; and the operator was continuing with a plan to add predictive wind shear capability to its aircraft.

Brakes Fail During Landing

**Airbus A320-200. Minor damage.
No injuries.**

On final approach to an airport in Wales, the flight crew observed a "STEERING" warning on the electronic centralized aircraft monitoring (ECAM) display and cycled the anti-skid and nosewheel steering ("A/SKID & N/W STRNG") switch to reset the brake and steering control unit (BSCU). Indications were that their action was successful, but after touchdown, the airplane did not decelerate normally; fully depressing the brake pedals had no effect.

The crew selected maximum reverse thrust and cycled the "A/SKID & N/W STRNG" switch and applied the brake pedals; again, fully depressing the brake pedals had no effect. They then selected the "A/SKID & N/W STRNG" switch to "OFF," and the captain applied the brakes. The airplane stopped about 40 meters (131 feet) before the end of the runway. Three main landing gear tires failed during the landing roll.

An investigation found that 10 seconds to 13 seconds elapsed before the crew recognized that pedal braking was ineffective. Because the flight warning computer does not actively monitor the BSCU, there was "no overt warning from the ECAM of the malfunction of the BSCU," the report said.

As a result of the investigation, the U.K. Air Accidents Investigation Branch recommended that Airbus improve the automated warnings to flight crews about the loss of braking system effectiveness and amend operating manuals and related material to "advise application of maximum reverse thrust as soon as a loss of braking performance is suspected following touchdown, rather than delay the application [while] awaiting confirmation that no braking is available."

Burst Tire Damages Hydraulic System

**Boeing 737-300. Minor damage.
No injuries.**

The flight crew conducted what appeared to be a normal takeoff from an airport in Scotland for a flight to Malta, but during climbout, they observed a rapid decrease in the "A" system hydraulic quantity. They were unable to retract the landing gear, and they observed the illumination of three red "gear unsafe" warning lights as well as two green "down and locked" lights. In addition, the "HYD" master caution light illuminated.

The crew leveled the airplane at 3,000 feet and told air traffic control (ATC) that they had a "technical problem which needed to be observed."

Five seconds after takeoff, the ground movement controller observed a white stream from the underside of the aircraft and told other ATC personnel, who told the flight crew. The crew calculated that the airplane was overweight for an immediate landing and decided to continue flying to reduce fuel.

While they flew the airplane in a holding pattern, they determined — with the help of ATC and maintenance personnel on the ground — that the left main landing gear had extended but that the left inboard main-wheel (no. 2) tire was either missing or damaged. About the same time, the crew of a landing airplane observed tire debris on the runway.

After about three hours, the airplane was landed safely. An investigation revealed that the no. 2 tire had shed its tread and separated from the wheel and that some of the debris had damaged the left main landing gear actuator and its hydraulic system, leading to a failure of the no. 1 engine hydraulic engine-driven pump.

An investigation showed that the tire was "close to its fully worn condition," the report said. In addition, the tire had been retreaded six times — the operator's limit for tires used on the airplane.

After the incident, the operator took several actions to prevent similar occurrences, including limiting to three the number of times its Boeing 737 tires could be retreaded, issuing maintenance instructions to clarify correct tire pressures and briefing flight crews on preflight tire inspections.

AIR TAXI/COMMUTER

Wings Sustain Structural Damage During Flight

De Havilland DHC-2 Beaver. Substantial damage. No injuries.

Daytime visual meteorological conditions prevailed for the sightseeing flight in a mountainous region of the United States. The pilot said that, as he flew the airplane at 11,000 feet to allow his passengers to view the highest mountain, the airplane began to shake violently.

"He said that he could not control the airplane and elected to shut down the engine in the event the engine was the cause of the problem," a preliminary accident report said.

The shaking continued until he slowed the airplane to about 80 miles per hour (70 knots). He restarted the engine and flew the airplane at a slow airspeed to an airport for landing. An examination of the airplane revealed structural damage to both wings.

The report said that the damage occurred during an encounter with turbulence "or possible aerodynamic flutter."

Baggage Truck Strikes Wing of Parked Airplane

Embraer EMB 145. Minor damage. No injuries.

The airplane was parked at the gate at an airport in Scotland and the crew was preparing to board passengers when the right wing was struck by a baggage truck that was being driven away from an airplane at the next gate. The wing penetrated the truck's windshield.

The accident report said that the driver of the truck probably was "concentrating on avoiding the left wing of the aircraft he had just driven away from and so did not notice the [incident airplane's] right wing, a situation [exacerbated] by the fact that he was also driving into bright sunshine."

Tail Strike Blamed on Aft CG

Saab-Scania AB SF340B. Minor damage. No injuries.

The airplane was being prepared for departure from an airport in Scotland while parked, facing into a wind gusting to 52 knots. After the engines were started and as the propeller condition levers were advanced, the airplane pitched backward, and the tail struck the ground.

The flight crew shut down both engines, and the airplane returned to a normal attitude.

The accident report said that the likely cause of the incident was "an extreme aft [center of gravity] caused by incorrect loading of the baggage and the unauthorized relocation of some of the passengers."

After the incident the operator said that captains should be given written confirmation that the baggage areas have been loaded in accordance with their instructions, that the cabin services manual should be updated to state that passengers may not be moved without the captain's permission and that before departure, cabin crewmembers should confirm the distribution of passengers in the airplane.

Airplane Aligned With Runway Edge Line in Predawn Takeoff

Cessna 550 Citation. No damage. No injuries.

Visibility of 6,000 meters (3.7 statute miles) prevailed for the pre-dawn takeoff from an airport in England. The crew received a takeoff clearance before reaching a holding point on the taxiway and continued onto the runway for the takeoff on a flight to Denmark. As the airplane accelerated through about 70 knots, the crew said that they felt a bump and the airplane yawed right.

The captain applied opposite rudder to correct the yaw, and the right wheel and the nosewheel moved onto a grassy area near the runway. The captain applied differential braking and increased right-engine power to return the airplane to the runway. He then slowed the airplane, taxied to the apron (ramp) and shut down.

The captain said later that the lead-in area to the runway was poorly lighted and that the runway did not have centerline lighting.

The copilot said that the "bump" might have been caused by the airplane hitting a rabbit, but no remains were found. Maintenance personnel found no problem that could have caused the yaw described by the crew.

The incident report said that flight data and marks on the ground indicated that the airplane "was lined up for takeoff on the runway edge line instead of the runway centerline. The commander's [captain's] report that the runway did not have centerline lighting, when in fact it does, also supports this conclusion."

As part of a refurbishment program, the airport operator has scheduled a review of runway ground markings and improvement of the ground lighting system.

Airplane Slides Off Runway During Landing With Gusty Headwind

Rockwell Commander 690A. Substantial damage. No injuries.

Nighttime instrument meteorological conditions prevailed for the approach and landing at an airport in the United States.

The pilots said that the instrument landing system (ILS) approach and landing on Runway 24 were "normal," but during the landing rollout, the airplane yawed right and the crew was unable to correct the yaw. The airplane slid sideways and stopped, partly on the runway and partly on the grass.

An investigation revealed no mechanical problems with the airplane.

Weather at the time included winds from 240 degrees at 15 knots with gusts to 25 knots.

Taxiing B-737 Strikes Parked Gulfstream

Gulfstream Aerospace GIV. Substantial damage. No injuries.

Boeing 737. Minor damage. No injuries.

Daytime visual meteorological conditions with visibility of 10 statute miles (16 kilometers) prevailed as a Boeing 737 was taxied from a ramp (apron) in preparation for takeoff from an airport in the United States. At the same time, the Gulfstream crew was preparing to start the engines, and ground marshallers were preparing to assist the Gulfstream crew in taxiing from the area.

The Boeing crew was not assisted by ground marshallers as they taxied from the same area.

"As the Boeing converged on the parked Gulfstream, the ground marshallers at the Gulfstream attempted to get the attention of the Boeing flight crew," the report said. "However, the left winglet of the Boeing struck the rudder of the Gulfstream."

Landing-gear Collapse Blamed On Displaced Hydraulic Line

**Cessna 177RG. Minor damage.
No injuries.**

Daytime visual meteorological conditions prevailed for the flight from Norway to Sweden. Before landing, when the pilot moved the landing gear selector to the "DOWN" position, the landing gear "did not move as anticipated," the accident report said.

The pilot attempted to extend the landing gear manually, and controllers in the airport air traffic control tower said that the landing gear appeared to be down. After landing, the nosewheel collapsed.

An investigation revealed that the airplane's hydraulic-fluid reservoir was empty; in addition, the hydraulic line for the left down-lock actuator "showed abrasion damage clearly caused by the gear of the right-hand undercarriage leg," the report said. Records showed that all hoses in the airplane's hydraulic system had been replaced about 10 flight hours (seven landings) before the incident.

The report said that the cause of the accident was "a hydraulic line becoming displaced during maintenance work and sustaining a leak when it came into contact with moving parts in the undercarriage mechanism."

Propeller Separates From Airplane During Descent

**Miles M.65 Gemini 1A. Minor damage.
No injuries.**

The airplane was being flown on a local daytime flight from an airport in England when, during descent at a low throttle setting, the pilot heard a thump and observed the left propeller "flying away after striking the nose of the aircraft," the incident report said.

The pilot conducted a landing at the airport, and the propeller, which was made of wood, was recovered from a nearby field.

Records showed that the last scheduled maintenance had been an annual maintenance check performed about six months before the incident; maintenance included a check of the tightness of the propeller attachment bolts. After maintenance, the airplane accumulated 24 flight hours before the incident. The airplane was nearly due for a six-month maintenance check.

The airplane was maintained according to the U.K. Civil Aviation Authority (CAA) basic light aircraft maintenance schedule (LAMS), which required that propeller tightness be checked every 50 flight hours or every six months. The manufacturer's original aircraft service manual, published in 1946, required a check of propeller attachment bolts every 10 flight hours. A subsequent manual required a check of propeller tightness every 25 hours if the propeller was a wood propeller.

The U.K. Air Accidents Investigation Branch recommended that CAA, "when approving the application of the [LAMS] to historic aircraft, review the appropriateness of the resulting inspection intervals against those of the original maintenance schedule, if this is available, and require out-of-phase maintenance actions where appropriate."

Mobile Phone Becomes Jammed in Airplane Controls

**Yakovlev Yak-52. Minor damage.
No injuries.**

During an aerobatics practice session in England, as the pilot performed a stall turn at 3,500 feet and ended the maneuver with the airplane in a 70-degree nose-low attitude, he felt a restriction on the controls. He closed the throttle and recovered the airplane from the dive, with "considerable loss" of altitude, the accident report said.

The pilot declared an emergency and returned to the departure airport for landing. He was unable to slow the descent rate before landing, and the airplane touched down heavily and bounced; the pilot said that he regained control before the second touchdown.

An investigation revealed a mobile telephone in the rear section of the fuselage. The incident report said that the telephone showed "considerable damage, which was consistent with it becoming trapped in the rear elevator quadrant."

The telephone had been taken into the airplane by a passenger two weeks before the incident flight. Because the earlier flight was not an aerobatic flight, the pilot had not taken measures to prevent loose articles in the cockpit. The telephone owner was unaware that the telephone had been lost.

The investigation also found that a barrier, which had been installed as a mandatory modification to prevent movement of loose articles to the rear of the airplane, had become detached from about 60 percent of its frame. The pilot said that he knew that the barrier was loose but that he had believed that the damaged area involved only a corner of the barrier.

The report said that the incident "highlights the need for the utmost vigilance with regard for foreign objects, particularly in aircraft used for aerobatics and with control systems vulnerable to loose articles."

ROTORCRAFT

Dislodged Exhaust Pipe Sends Smoke, Heat Into Cockpit

Enstrom 280C. Substantial damage. No injuries.

For six months before the accident flight, the helicopter had been out of service for maintenance. During the first few days after being returned to service, the helicopter was flown in five flights totaling about 3 1/2 hours. Before flight each day, the pilot conducted an inspection, including a check of the engine oil level.

During the accident flight, the pilot observed light smoke in the cockpit, followed by "the feeling of heat at his back," the accident report said. The pilot began an emergency descent with power; he said that about 600 feet above ground level, downwind from the intended landing area, the engine apparently stopped. During the subsequent landing, the helicopter rolled over.

Later, the pilot said that he was uncertain about whether the engine actually had stopped and "candidly suggested that, in his concern about the fire and carrying out an immediate landing, he may simply have mishandled the landing, possibly by flaring late from a high rate [of] descent."

The investigation found that a short exhaust pipe had detached from the turbocharger, "allowing the exhaust to impinge directly on the inside of the [helicopter] skin," the report said.

A clamp that secured the exhaust pipe had fractured during the flight because of fatigue, causing the exhaust pipe to become dislodged.

"This pipe also connected to a bypass pipe from the engine exhaust system, and once dislodged, this allowed exhaust from close to the cylinders to be directed at the bulkhead immediately behind the pilot," the report said. "The entire engine compartment would have filled with exhaust fumes, accounting for smoke in the cockpit."

Corroded Skid Breaks in Helicopter's 'Mild' Contact With Ground

Bell 206B JetRanger. Minor damage. No injuries.

The helicopter was being flown from an airport in Ireland for an annual license proficiency check on a qualified pilot. As the pilot conducted one of the required exercises — a stuck left pedal, the helicopter touched the ground.

The authorized flight examiner said that the maneuver requires flying the helicopter to a very low hover, applying collective and touching down with level skids and no forward motion.

The report said, "The [pilot], who felt that there may have been some slight forward speed but with relatively mild ground contact, was therefore quite surprised that part of the right rear skid broke off on landing."

An investigation revealed severe corrosion in parts of the skid's aluminum tube that extended for about 40 percent of the tube's circumference and "would have weakened the tube significantly," the report said. "High-strength aluminum alloys are prone to this type of corrosion, particularly in marine environments."

The skid had been inspected in accordance with maintenance manual instructions about three months before the incident.■

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