National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: July 26, 2011

In reply refer to: A-11-70 through -74

The Honorable J. Randolph Babbitt
Administrator
Federal Aviation Administration
Washington, DC 20591

On March 22, 2009, about 1432 mountain daylight time, a Pilatus PC-12/45, N128CM, was diverting to Bert Mooney Airport (BTM), Butte, Montana, when it crashed about 2,100 feet west of runway 33 at BTM. The pilot and the 13 airplane passengers were fatally injured, and the airplane was substantially damaged by impact forces and a postcrash fire. The airplane was owned by Eagle Cap Leasing of Enterprise, Oregon, and was operating as a personal flight under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91. The flight departed Oroville Municipal Airport (OVE), Oroville, California, on an instrument flight rules flight plan with a destination of Gallatin Field, Bozeman, Montana (BZN). Visual meteorological conditions prevailed at the time of the accident.

The National Transportation Safety Board (NTSB) determined that the probable cause of this accident was (1) the pilot's failure to ensure that a fuel system icing inhibitor was added to the fuel before the flights on the day of the accident; (2) his failure to take appropriate remedial actions after a low fuel pressure state (resulting from icing within the fuel system) and a lateral fuel imbalance developed, including diverting to a suitable airport before the fuel imbalance became extreme; and (3) a loss of control while the pilot was maneuvering the left-wing-heavy airplane near the approach end of the runway.[1]

Background

The accident occurred during the third and final flight leg of the day. The airplane had previously flown from its base of operations at Redlands Municipal Airport (REI), Redlands, California, to Nut Tree Airport (VCB), Vacaville, California, and then from VCB to OVE. Analysis of data downloaded from the airplane's central advisory and warning system (CAWS)[2] showed that, during the flight from REI to VCB and the accident flight leg, a low fuel

[1] For more information, see *Loss of Control While Maneuvering, Pilatus PC-12/45, N128CM, Butte, Montana, March 22, 2009*, Aircraft Accident Report NTSB/AAR-11/05 (Washington, DC: National Transportation Safety Board, 2010), which is available on the NTSB's website at <http://www.ntsb.gov/publictn/2011/AAR1105.pdf>.

[2] Nonvolatile memory data downloaded from the airplane's CAWS contained information about the airplane's 480 flights made during the 2 years before the accident. For 477 of the 480 flights, the left and right fuel boost pumps activated a total of 29 times. These activations were consistent with the operation of the automatic fuel

pressure state existed, which necessitated the automatic operation of the left and right fuel boost pumps to provide the required fuel pressure to the engine. The flight from REI to VCB concluded uneventfully. However, for the accident flight leg, the low fuel pressure state and a restricted flow of fuel from the left wing tank led to a 1,300-pound left-wing-heavy fuel imbalance,[3] which ultimately resulted in a loss of control as the pilot maneuvered the airplane near the approach end of the runway.

Pilatus PC-12 airplane flight manual (AFM) procedures required the pilot to (1) monitor the fuel quantity indicator in the cockpit to ensure fuel symmetry between the left and right fuel tanks during flight and (2) land the airplane as soon as practical if the maximum allowable fuel imbalance (about 150 pounds) was exceeded and the difference could not be balanced.[4] During the accident flight, the pilot began to divert to BTM about 30 minutes after the maximum allowable fuel imbalance was reached, even though several closer airports along the airplane's route of flight were available. If the pilot had diverted earlier in the flight to one of these airports, the outcome of this flight would likely have been different because the airplane would have had a less severe fuel imbalance and the pilot would not have had to contend with the airplane's deteriorating performance as the imbalance steadily progressed.

The low fuel pressure state during the two flight legs and the restricted flow of fuel from the left wing tank during the accident flight leg resulted from icing within the fuel system with an initial concentration at the fuel filter. It is important to note that the fuel system continued to provide fuel to the engine throughout the flight, even with the low fuel pressure state and the degraded performance of the left-side fuel system.

The airplane had been serviced with fuel on the day before the accident and after landing at VCB, but the pilot failed to ensure that a fuel system icing inhibitor (FSII) had been added to the fuel. The Pilatus PC-12 AFM, section 2, Limitations, dated March 30, 2001, stated that a FSII "must be used for all flight operations in ambient [outside air] temperatures below 0º C." On a standard day, the temperature is 0° C at 7,500 feet, so most PC-12 flights would require the use of a FSII.[5]

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balancing system to laterally balance the fuel load. For the three remaining flights—REI to VCB (on the day of the accident), the accident flight leg (OVE en route to BZN with a divert to BTM), and a flight occurring on October 16, 2007 (from Cabo San Lucas, Mexico, to San Diego, California)—both fuel boost pumps activated 176, 337, and 260 times, respectively.

[3] The fuel supplied to the engine was being drawn solely from the right wing fuel tank by the right fuel boost pump. With the fuel return system operating normally, any excess fuel flow to the engine would have been returned and distributed equally to both fuel tanks. Thus, the left and right fuel tanks were equally receiving fuel through the fuel return lines, but the left-wing-heavy fuel imbalance continued to increase during the flight because fuel was only being drawn from the right fuel tank. The increasing fuel level in the left tank and the accelerated depletion of the fuel from the right tank should have been apparent to the pilot because that information would have been presented on the fuel quantity indicator in the cockpit.

[4] In addition to providing fuel system pressure when a low fuel pressure state exists, fuel boost pumps balance the fuel load between the left and the right wing fuel tanks.

[5] According to the Federal Aviation Administration's Instrument Flying Handbook, in the standard atmosphere, sea level pressure is 29.92 inches of mercury, and the temperature is 15° C. The standard lapse rate for temperature is a 2° C decrease per 1,000-foot increase.

The NTSB obtained surveillance video from VCB that showed the accident airplane's arrival at the VCB self-service fueling island. The video showed the pilot performing some parts of the required preflight inspection. However, the video showed no evidence that the pilot had sampled fuel from either of the underwing fuel tank drains or the fuel filter drain. Also, the surveillance video did not show any evidence that the pilot examined the fuel filter bypass indicator to ensure that it was flush with the filter housing assembly.[6] If the pilot had performed a complete preflight inspection before the flight to OVE, he would have had an opportunity to detect whether ice crystals or water were present in the fuel and determine whether the fuel filter bypass indicator was extended, which could have explained the reason for the fuel boost pump advisories annunciated during the preceding flight.

Fuel Limitations

Section 2 of the PC-12 AFM, Limitations, detailed the requirements for FSIIs. The section stated that a FSII must be used for all flight operations in ambient temperatures below 0° C. The section further specified that the concentration of FSII must be between 0.06 and 0.15 percent by volume. A caution advised operators and pilots that the correct mix of anti-icing additive with the fuel was important because concentrations greater than 0.15 percent by volume would cause damage to the protective primer and sealants of the fuel tanks, the fuel system, and engine components. Section 8 of the AFM, Handling, Servicing, and Maintenance, contained the same caution but also included the statement, "concentrations [of FSII] lower than 0.06 [percent by volume] may not be enough to inhibit ice formation."

The NTSB is aware of three other turbine-powered single-engine airplanes that require a FSII: the Cessna 208B, Piper PA-46-500TP, and Socata TBM-700C.[7] The AFM for each of these airplanes provided information about the correct FSII usage directly in the limitations section or included a reference in the limitations section to another AFM section that contained specific FSII information. However, the use of cautions and warnings to highlight FSII information was inconsistent among the manuals.

Title 14 CFR Part 23.1583, Operation Limitations, paragraph (b), states that AFMs must specify powerplant limitations, including the fuel designation for turbine-powered airplanes. However, the powerplant limitations information does not reference the requirement for FSIIs or other fuel additives. If a FSII is required by an airframe manufacturer, then the additive is a critical fuel system limitation, and the omission of a FSII from fuel (when required) could lead to a situation resulting in personal injury or loss of life, as demonstrated by the circumstances of this accident.

Advisory Circular (AC) 25.1581-1, "Airplane Flight Manual," dated July 14, 1997, identified the information that must be provided in AFMs for transport-category airplanes and

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[6] The fuel filter has a spring-loaded bypass valve that would open and allow fuel to bypass the filter if it were blocked. The valve has an indicator that extends a red button when fuel has bypassed the fuel filter.

[7] The Prist Aerospace Products website (<http://www.pristaerospace.com>, accessed June 10, 2011) indicated that the following twin-engine aircraft require a FSII: Beechcraft Raytheon Beechjet 400 and Starship; Bombardier Learjet 23, 24, 25, 28, 29, and 35/36; Cessna Corsair/Conquest and Citation I and II; Hansa HFB-320; Mitsubishi MU-2 and MU-300; and Piaggio Avanti. The website also indicated that some very light jets (referred to as VLJs) require a FSII.

provided guidance regarding the form and content of the approved portions of the AFMs. The AC stated that AFM operating procedures and techniques could be categorized as warnings or cautions. A warning was defined as "an operating procedure or technique that may result in personal injury or loss of life if not followed." A caution was defined as "an operating procedure or technique that may result in damage to equipment if not followed."

The safety hazard involving fuel system ice accumulation could be mitigated if manufacturers of aircraft requiring FSII for operation placed a warning within the limitations section of their respective AFMs that described the need to ensure that fuel contained the additive in a concentration between the specified minimum and maximum values. Therefore, the NTSB recommends that the Federal Aviation Administration (FAA) amend certification requirements for aircraft requiring fuel additives, including FSIIs, so that those limitations are highlighted by a warning in the limitations section of the AFM. The NTSB further recommends that the FAA require all existing certificated aircraft (both newly manufactured and in-service aircraft) that require fuel additives, including FSIIs, to have those limitations highlighted by a warning in the limitations section of the AFM.

Fuel Filler Placards

The PC-12 fuel filler placard, which was located near each fuel filler port, specified the total fuel capacity (203 gallons) and usable capacity (201 gallons) for each fuel tank and the type of fuel to be used (Jet A, Jet A-1, or Jet B). The placard, however, did not note the requirement for a FSII during flight operations with outside air temperatures below 0º C. The PC-12 fuel filler placard was consistent with the requirements of 14 CFR 23.1557, "Miscellaneous Markings and Placards," which stated that fuel filler openings for turbine-powered airplanes must be marked at or near the filler cover with the words "Jet Fuel" and either the permissible fuel designations or references to the AFM for the permissible fuel designations. The regulation does not specifically require manufacturers to reference any necessary fuel additives on the fuel filler placard.

AC 20-29B, "Use of Aircraft Fuel Anti-Icing Additives," indicated that the use of a FSII would meet the provisions of 14 CFR 25.997, "Fuel Strainer or Filter," paragraph (b), which required, at the time of the AC's issuance, "a means to automatically maintain the fuel flow if ice-clogging of the [fuel] filter occurs." Further, the AC stated that, for aircraft requiring a FSII, placards near the fuel filler cover should indicate that the fuel must contain the anti-icing additive.

Title 14 CFR 23.997(d) contained the same requirement as 14 CFR 25.997(b) but for normal- and commuter-category aircraft with turbine engine fuel systems. These regulations, however, did not provide protection for ice accumulation in other fuel system components. As a result, the requirements of both regulations were subsequently included in 14 CFR 23.951 and 25.951, "Fuel System, General." Specifically, sections 23.951(c) and 25.951(c) both required that the entire fuel system be capable of sustained operation throughout its flow and pressure range with water-saturated fuel cooled to the most critical condition for icing to be encountered during operation. It is important to note that the FAA did not include a related provision from AC 20-29B in sections 23.951(c) and 25.951(c) when they first became effective or in any revision to the regulations since that time: for manufacturers of airplanes that used a FSII for meeting regulatory requirements to indicate, on fuel filler placards, the need to add a FSII to the fuel.

The Cessna 208B, Piper PA-46-500TP, and Socata TBM-700C all have fuel filler placards with a reference to FSIIs in addition to the information required by 14 CFR 23.1557. These fuel filler placards state, “anti-ice additive required. See Pilot’s Operating Handbook for other approved fuels, quantity and type of additive.” This placarded information provides a prominent reminder to pilots and fuel service personnel of the importance of a FSII during flight operations. The NTSB concludes that the safety hazard involving fuel system ice accumulation could be mitigated if fuel filler placards installed aboard aircraft requiring a FSII specified that requirement. Therefore, the NTSB recommends that the FAA amend aircraft certification fuel placarding requirements so that aircraft requiring fuel additives, including FSIIs, have a fuel filler placard that notes this limitation and refers to the AFM for specific information about the limitation. The NTSB further recommends that the FAA require all existing certificated aircraft (both newly manufactured and in-service aircraft) that require fuel additives, including FSIIs, to have a fuel filler placard that notes this limitation and refers to the AFM for specific information about the limitation.

Guidance on Fuel System Icing Prevention

On October 22, 1981, the FAA issued AC 20-113, “Pilot Precautions and Procedures to Be Taken in Preventing Aircraft Reciprocating Engine Induction System and Fuel System Icing Problems.” Although this AC detailed pilot precautions and procedures to prevent fuel system icing in aircraft with reciprocating (piston-driven) engines, including the use of anti-icing fuel additives, no AC addresses the prevention of fuel icing problems on turbine engine-powered aircraft. It is possible that turbine engine-powered aircraft were not addressed in AC 20-113 because most Part 91 and 135 aircraft operations at that time were conducted with piston engine-powered aircraft. However, many aircraft that are currently operating under Parts 91 and 135, such as the Pilatus PC-12, have turbine-powered engines. Such aircraft operate in cold temperatures and at high altitudes with service ceilings ranging from flight levels 230 to 310. As a result, pilots and operators of turbine engine-powered aircraft would also benefit from FAA guidance on preventing fuel system icing problems.

Pilots and operators of turbine-powered airplanes would further benefit from FAA guidance advising that the use of a FSII could substantially inhibit fuel system icing during flights at high altitudes and cold temperatures. Although pilots and operators of these airplanes should already understand the importance of adhering strictly to the limitations outlined in an airplane’s AFM for operations requiring a FSII, FAA guidance would be another resource that promotes awareness of, and adherence to, required procedures designed to prevent fuel system icing problems in turbine-engine aircraft.[8] In addition, it is important for such guidance to clearly explain the potential consequences of either failing to add a FSII when required, as demonstrated by this accident, or having an incorrect concentration of a FSII in jet fuel. Further, the guidance

[8] Pilots could apply this guidance to preflight planning activities, including (1) determining whether fuel premixed with a FSII would be available at departure airports or whether the FSII would need to be directly injected into the fuel and (2) learning whether a FSII would be available at destination airports or airports along the airplane’s route of flight (if refueling would be needed) and, if not, determining what contingency plans could be made.

could be a means for informing pilots and operators of the availability of portable test kits to determine whether the correct concentration of a FSII is present in jet fuel.

The NTSB concludes that FAA pilot and operator guidance on the use of FSIIs would help raise awareness of the need to include this additive in turbine engine-powered aircraft with fuel systems that require the additive. Therefore, the NTSB recommends that the FAA issue guidance on fuel system icing prevention that (1) includes pilot precautions and procedures to avoid fuel system icing problems aboard turbine engine-powered aircraft and (2) describes the possible consequences of failing to use a FSII, if required by the AFM, especially during operations at high altitudes and in cold temperatures. This recommendation could be addressed by augmenting the guidance provided in AC 20-113.

Crash Protection for Airplane Occupants

The accident airplane was configured with eight passenger seats in the cabin and two pilot seats in the cockpit. Because each flight on the day of the accident was a single-pilot operation, the eight seats in the cabin and the right seat in the cockpit were available to the passengers.

The pilot indicated on the flight plan that a total of nine people would be on board the airplane for the planned trip from OVE to BZN, but a total of 14 people (the pilot and 13 passengers) were aboard the airplane. Thus, the operation was not in compliance with the Pilatus PC-12 AFM requirement limiting the maximum number of passengers to nine. Also, the operation was not in compliance with 14 CFR 91.9, “Civil Aircraft Flight Manual, Marking, and Placard Requirements,” which states in paragraph (a), “no person may operate a civil aircraft without complying with the operating limitations specified in the approved Airplane or Rotorcraft Flight Manual.”

The owner of the airplane who organized the trip stated that the airplane had transported the same number of passengers on a previous flight. For that flight and the accident flight leg, the owner believed that he and the pilot “were not pushing the envelope” because “the trip was within weight and balance limits,” but the owner acknowledged that “there were just not enough seatbelts” for every passenger.

Except for the pilot and the adult passenger in the right cockpit seat, the NTSB was unable to determine the seating position for the airplane occupants. The airplane owner who organized the trip stated that the adults could hold the children on their laps. However, only one of the seven children was under the age of 2 years and was permitted by 14 CFR 91.107, “Use of Safety Belts, Shoulder Harnesses, and Child Restraint Systems,” paragraph (a)(3)(i), to be held on the lap of an adult. The six other children ranged in age from 3 to 9 years. Because the bodies of four of these children were found farthest from the impact site, the NTSB concludes that at least four of the seven children on board the airplane were not restrained or were improperly restrained.

Proper restraint use is one of the most basic and important tenets of crashworthiness and survivability. However, 14 CFR 91.107 does not specifically prohibit multiple occupants from sharing one seating position.[9] Research by the United Kingdom's Civil Aviation Authority (CAA) documented problems with dual occupancy of a seat and restraint system designed for one adult passenger. Specifically, the CAA's research found that seating two children in the same seat and restraining both under one lap belt[10] (1) provided neither child with the same protection that they would have received if they were in separate seats and (2) increased the risk of both children sustaining head and body injuries during an impact.[11] In addition, even though section 91.107 allows children who are less than 2 years of age to be held on the lap of an adult, recent FAA guidance emphasizes that the safest place for a child under 2 years of age during turbulence or an emergency is in an approved child restraint system and not on an adult's lap.[12]

The NTSB concludes that, although the number of passengers on board the airplane during the final flight leg did not comply with the PC-12 AFM limitation requiring no more than nine passengers, the four additional passengers on board the airplane did not directly affect the outcome of the accident. Further, although the BTM accident was not survivable, the NTSB concludes that, for survivable accidents, passengers aboard airplanes operating under Part 91 would be afforded better crash protection if each seat and restraint system were limited to only one passenger and children less than 2 years of age were restrained in an approved child restraint system.

On August 11, 2010, the NTSB issued Safety Recommendation A-10-121, which asked the FAA to "amend 14 *Code of Federal Regulations* Part 91 to require separate seats and restraints for every occupant." This recommendation was issued as a result of the NTSB's concern that, if the FAA were to continue allowing multiple occupants aboard airplanes operating under Part 91 to share a single seat position[13] and a single restraint system, then those occupants would not benefit from the improved protection provided by the crashworthiness requirements of Part 23.[14] On October 14, 2010, the FAA stated that it was reviewing these recommendations to

[9] In January 2010 correspondence to the NTSB, the FAA stated that, according to section 91.107, multiple (two or more) occupants are allowed to share one seat and one restraint system as long as "the seat usage conformed with the limitations contained in the approved portion of the Airplane Flight Manual" and "the belt was approved and rated for such use."

[10] Each passenger seat aboard the accident airplane was equipped with lap and shoulder harness restraints. Although the CAA's research was conducted using lap belts, the NTSB believes that the findings would also apply to multiple occupants sharing a restraint system with a shoulder harness because the effectiveness of the shoulder harness would be reduced and the risk of injury to the occupants would thus increase. A shoulder harness is designed to prevent injury as a result of an occupant's head and torso flailing in an accident with a horizontal component. A single shoulder harness cannot provide restraint for two occupants because the harness would not fit either occupant properly.

[11] Roger N. Hardy, "Dual Child Occupancy of an Aircraft Seat," CAA Paper 93013 (London, United Kingdom: Civil Aviation Authority, 1993).

[12] This information was obtained from the FAA's website <http://www.faa.gov/passengers/fly_children/crs> (accessed June 10, 2011).

[13] The NTSB recognizes that some airplanes operating under Part 91 are configured with seats that have more than one seating position. For example, the Bombardier Challenger CL-600 involved in the February 2, 2005, accident in Teterboro, New Jersey, was configured with a divan that had three separate seating positions.

[14] Title 14 CFR 23.562, "Emergency Landing Dynamic Conditions," paragraph (a)(1), stated that each seat and restraint system for use in an airplane must be designed to protect each occupant during an emergency landing when "proper use is made of seats, safety belts, and shoulder harnesses provided for in the design." Section 23.562 also addressed dynamic testing with an anthropomorphic test dummy (ATD) and required, among other things, that the shoulder harness remain on the ATD's shoulder and the safety belt remain on the ATD's pelvis during the impact.

determine whether a revision of the current interpretation of section 91.107 would be appropriate. The FAA indicated that it would keep the NTSB informed about the FAA's progress on the recommendation. On January 31, 2011, the NTSB classified Safety Recommendation A-10-121 "Open—Acceptable Response" pending completion of the recommended action.

On June 23, 2011, the FAA published its Clarification of Prior Interpretations of the Seat Belt and Seating Requirements for General Aviation Flights. The FAA's proposal did not include a provision to prohibit the shared use of a seat and restraint system, which is currently allowed under Part 91. Instead, the proposal relies on the "good judgment of the pilot" to determine the proper method of restraint for children during operations conducted under Part 91. The NTSB is disappointed that the FAA did not provide true clarification on the issue, and the NTSB remains concerned that the improved crashworthiness standards required by Part 23 regulations are negated when two or more occupants share a seat and a restraint.

As previously stated, Safety Recommendation A-10-121 asked the FAA to amend Part 91 to require separate seats and restraints for every occupant. The FAA's proposal shows that the agency does not intend to amend the regulation. Title 14 CFR 121.311, "Seats, Safety Belts, and Shoulder Harnesses," and 135.128, "Use of Safety Belts and Child Restraint Systems," require separate seats and restraints for each passenger age 2 years and older. The addition of such a requirement to Part 91 regulations would help ensure the proper use of seating and restraint systems during this type of operation.

The NTSB continues to believe that Part 91 regulations do not promote effective occupant protection because multiple occupants sharing one seat and restraint system are less likely than single occupants to withstand deceleration forces during a survivable crash. As a result, Safety Recommendation A-10-121 is classified "Open—Unacceptable Response."

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Amend certification requirements for aircraft requiring fuel additives, including fuel system icing inhibitors, so that those limitations are highlighted by a warning in the limitations section of the airplane flight manual. (A-11-70)
>
> Require all existing certificated aircraft (both newly manufactured and in-service aircraft) that require fuel additives, including fuel system icing inhibitors, to have those limitations highlighted by a warning in the limitations section of the airplane flight manual. (A-11-71)
>
> Amend aircraft certification fuel placarding requirements so that aircraft requiring fuel additives, including fuel system icing inhibitors, have a fuel filler placard that notes this limitation and refers to the airplane flight manual for specific information about the limitation. (A-11-72)

Neither of these conditions could be met with multiple occupants sharing a single seat and restraint system, as allowed by 14 CFR 91.107. The NTSB recognizes that many airplanes operating under Part 91 were certified before the time that the improved crashworthiness standards were adopted but believes that occupants of those airplanes would also benefit from single-occupant use of seats and restraint systems.

> Require all existing certificated aircraft (both newly manufactured and in-service aircraft) that require fuel additives, including fuel system icing inhibitors, to have a fuel filler placard that notes this limitation and refers to the airplane flight manual for specific information about the limitation. (A-11-73)

> Issue guidance on fuel system icing prevention that (1) includes pilot precautions and procedures to avoid fuel system icing problems aboard turbine engine-powered aircraft and (2) describes the possible consequences of failing to use a fuel system icing inhibitor, if required by the airplane flight manual, especially during operations at high altitudes and in cold temperatures. (A-11-74)

Also, the National Transportation Safety Board reclassifies Safety Recommendation A-10-121 “Open—Unacceptable Response.”

> Amend 14 *Code of Federal Regulations* Part 91 to require separate seats and restraints for every occupant.

In addition, the National Transportation Safety Board made four recommendations to the European Aviation Safety Agency.

In response to the recommendations in this letter, please refer to Safety Recommendations A-11-70 through -74. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our secure mailbox. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman HERSMAN, Vice Chairman HART, and Members SUMWALT, ROSEKIND, and WEENER concurred with these recommendations.

[Original Signed]

By: Deborah A.P. Hersman
Chairman