NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

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Forwarded to:

Honorable J. Lynn Helms
Administrator
Federal Aviation Administration
Washington, D.C. 20591

SAFETY RECOMMENDATION(S)

A-83-3 through -11

During the period 1975 to 1981, there were 396 engine failure or malfunction accidents in United States general aviation aircraft involving water in the fuel as a cause/factor. These accidents involved, primarily, small, single-engine airplanes and resulted in 72 fatalities, serious injuries to 93 persons, and minor injuries to 127 persons. Engine stoppage because of water in the fuel occurred most often during the takeoff and initial climb phase of flight, and frequently involved older, high-wing Piper airplanes with metal fuel tanks such as the Piper Models J-3, PA-12, PA-18, and PA-22; low-wing agricultural airplanes such as the Piper Pawnee (Model PA-25) and the Cessna Agwagon (Model C-188); and high-wing Cessna airplanes, both old and new, with rubberized bladder-type fuel cells such as Cessna Models C-180, C-182, C-185, C-206, and C-207. The Safety Board believes that many accidents involving water in the fuel can be prevented and that the Federal Aviation Administration (FAA) should act immediately to address this fuel problem involving general aviation airplanes.

In airplanes such as the Cessna models that have flexible, rubberized bladder-type fuel cells in their wings, water can become entrapped or dammed up within the cells because of the irregular surfaces, wrinkles, or ridges in the cells. As a result, any water in the cells may not flow or statically migrate to the cell sump, where it can be detected routinely and drained through quick drains during a normal preflight inspection. Instead, the water may remain undetected even after repeated samples are taken from the quick drains while the airplane is in its normal ground attitude. Even if some water is detected during the preflight inspection and the cell is drained until no more water is found, there may still be water entrapped within the cell. This potential hazard may be more prevalent in airplanes with leaky fuel caps because air flowing over the wing may then cause a partial vacuum within the cell, resulting in its deformation or in the formation of pockets.

In a test conducted by the Safety Board on a Cessna Model C-182P, 32 ounces of water were placed in an essentially full, left-wing bladder fuel cell. However, after allowing the water to settle, fuel samples taken from the cell's quick drain, such as might be taken during a normal preflight procedure with the airplane in a level position, disclosed no evidence of water. The wings of the airplane were then agitated to disperse the water and to promote drainage, and the tail of the airplane was lowered and held to the ground in accordance with Cessna Owner Advisory SE 82-36A to provide a greater slope or inclined surface toward the quick drain. The drainage of several quarts of fuel resulted in the drainage of only 5 ounces of the water. With the tail held down and the left wing jacked up, continued sampling resulted in the drainage of an additional 10 to 12 ounces of water. However, the remaining 15 to 17 ounces of water could not be drained despite repeated attempts to do so; the water remained entrapped within the fuel cell. Removal of this water required complete drainage and swabbing of the cell. During this process, the cell was inspected for integrity of attachment. All of the cell hangers or snaps were secured, but the interior of the cell was wrinkled.

To determine if these test results were typical of the drainage characteristics of Cessna rubberized bladder fuel cells, a second test was performed on a Cessna Model C-182Q. For this test, performed for the Safety Board on February 8, 1983, by the University of Illinois' Institute of Aviation, 3,500 milliliters (about 1 gallon) of red-dyed water was placed in the airplane's essentially full, right-wing bladder fuel cell and allowed to settle. With the airplane in a level position, the contents of the right-wing fuel sump were drained into a large calibrated Pyrex container. About 1,250 milliliters of the red-dyed water drained immediately. The blue, 100 low-lead fuel then started to drain continuously, resulting in a clear and distinct red/blue water/fuel color boundary. The sump was drained until the total fluid sample (water and fuel) was about 3,500 milliliters, but there was no further evidence of any water. A 3,500-milliliter fluid sample, which was drained from the fuel system low point near the fuel selector (from a drain valve installed there for the test), contained only about 100 milliliters of the red-dyed water. The tail of the airplane was then lowered to and held on the ground, and draining of the right-wing fuel sump was resumed. About 850 milliliters of water drained immediately. Continued drainage until the total fluid sample was about 3,500 milliliters produced no further evidence of any water. With the airplane in this tail-low position, the right side of the airplane was jacked up, and as much additional water as possible was obtained from the right-wing fuel sump and the installed drain at the low point of the fuel system. All of the individual water samples collected were poured into the calibrated Pyrex container, and the total water was about 2,900 milliliters. Further fuel sampling with the airplane in the positions discussed disclosed no further evidence of any water.

The right-wing fuel cell cover plate and adapter were removed from the Cessna Model C-182Q to facilitate examination of the interior of the cell. The installation was secure and correct, but ridges and wrinkles were noted throughout the cell, together with beads of water and small isolated puddles. More importantly, however, examination of the aft, inboard corner of the cell, in the area of the fuel sump and finger strainer, disclosed a ridge extending from the aft trailing edge to the inboard side of the cell at a 45° angle. The ridge blocked considerable fluid adjacent to this area and prevented fluid from reaching the sump. The fluid was sponged and measured; it included about 500 milliliters of the red-dyed water. While the amount of water blocked by the ridge was substantial, the total quantity entrapped and prevented from reaching the sump would have been considerably larger if the airplane's tail and right wing had not been lowered and jacked up, respectively, as previously described.

These tests illustrate that preflight fuel sampling procedures, even when carried to an extreme, may not be fully effective in eliminating some substantial accumulations of water from Cessna bladder fuel cells. The Safety Board believes that the only reliable means of eliminating all of the water that may be entrapped within these fuel cells is to drain them completely, purge them with fresh air, and swab them to eliminate all traces of fuel and/or water. Other fuel system components, including fuel header tanks, carburetor bowls, fuel strainers and fuel lines between the strainer, and the low point of the fuel system, also should be drained at the same time. The Safety Board concludes that the FAA should issue an Airworthiness Directive (AD), applicable to Cessna

Models C-180, C-182, C-185, C-188, C-206, and C-207 with rubberized bladder fuel cells, requiring this action.

Since normal preflight procedures do not always detect or eliminate water from the bladder fuel cells of the Cessna airplanes discussed above, the Safety Board believes that a fuel system design change is warranted. Such a change might involve incorporating positive water collectors with quick drains at low points in the fuel system downstream of the bladder fuel cells, or appropriate modification of the fuel header or reservoir tanks already installed in some Cessna airplanes. One such water collector system was approved by the FAA on June 22, 1981, in Supplemental Type Certificate (STC) SA 4351WE, which describes a fuel line water drain system applicable to various Cessna Model C-182 series airplanes. According to the STC holder, the system entraps and stores any water that may flow from the fuel cells, thereby preventing the water from reaching and stopping the engine. Quick drains provide for easy, reliable inspection of the collector's contents and routine elimination of any water accumulated therein. Since the fuel strainer (attached to the firewall) is itself a water collector, consideration might be given to increasing its size to accomplish the same objective.

The most recent suspected water-in-fuel accident involving a Cessna Model C-182 airplane with bladder fuel cells occurred on February 3, 1983, at Weyers Cave, Virginia. Because of evidence of water in the fuel system prior to departure, both the pilot and a mechanic had attempted to remove the water through extensive draining of the fuel cells. Nonetheless, the airplane crashed following a loss of engine power just after takeoff, killing one passenger and seriously injuring two others.

The substantial quantity of water often found within bladder fuel cells or other types of fuel cells can occur as a result of condensation and/or taking on contaminated fuel, but it is often the result of leakage around deteriorated fuel filler cap seals or corroded fuel cap adapters in airplanes stored outdoors and exposed to heavy rain. This leakage occurs particularly frequently in airplanes that have flush-type fuel caps, such as those used on many Cessna airplanes, or in airplanes with fuel filler cap wells or recesses. Collected precipitation remains adjacent to the sealing surfaces for relatively long periods. Thus, the possibility of water entering Cessna bladder fuel cells is increased considerably by misaligned, contaminated, or deteriorated fuel cap seals; faulty vent valves; or corroded adapters which prevent proper sealing of the fuel caps. Therefore, the Safety Board believes that the FAA, in addition to requiring the recommended purging process, should issue an AD requiring a concurrent fuel filler cap leak test in accordance with Cessna Owner Advisory SE 82-34A for Cessna Models C-180, C-182, C-185, C-188, C-206, and C-207 with rubberized bladder fuel cells. If leakage is detected, compliance with Cessna Service Letter SE 80-59, "Sealing of Flush Type Fuel Caps," should be required.

According to information from the FAA's Maintenance Analysis Center, the flush plastic fuel caps installed on many Cessna airplanes may be subject to warping, cracking, or other service problems, which can cause fuel siphoning or result in fuel contamination. These service difficulties are reflected in reported comments such as: "warped red plastic fuel caps, sun exposure may be a factor;" "plastic caps age and become brittle;" "considerable amount of water found in fuel, apparently leaking through plastic caps during rains, seals appear good;" "plastic fuel tank cap will not hold shape and will not seal with new seal, fuel tank siphoned empty;" "plastic crystalized from weather and broke;" and "found fuel cap deformed [and] leaking." Moreover, the number of service difficulty reports relating to fuel filler cap problems increased after large quantities of the plastic caps were installed in accordance with AD 79-10-14. As a result, the Safety Board believes that the FAA should conduct an engineering evaluation of Cessna's flush plastic fuel caps to determine their sealing/venting characteristics under various critical service conditions, including extremes of temperature. If deficiencies are noted, appropriate action should be taken regarding the design of these caps.

On January 13, 1983, the FAA published Notice of Proposed Rulemaking (NPRM) 82-CE-38-AD in the Federal Register. This notice, which resulted from incidents involving fuel loss, erroneous fuel quantity indications, and undrainable water in bladder fuel cells, proposes the adoption of a new AD applicable to Cessna Models C-182, C-182A through C-182Q, and CR-182 airplanes equipped with bladder fuel cells and a single primary fuel tank vent. The proposed AD would require the installation of a placard warning of the hazards of leaky fuel caps and mandate repetitive inspections of the airplanes for indications of fuel tank cap leakage. The Safety Board believes that the FAA should consider the comments herein regarding Cessna fuel caps and bladder fuel cells before acting on the proposed rule.

The older Piper airplanes and the original versions of the Piper PA-25 were not equipped with quick drains in the fuel sumps or other means for routine preflight detection and elimination of water directly from the fuel tanks. Originally, a fuel strainer with a glass bowl was attached to the firewall of the older Piper airplanes to provide for fuel system drainage, and Piper recommended that it be checked regularly for evidence of fuel contamination. Later, aluminum strainers with quick drain valves were incorporated. However, for various reasons, including the relative orientation of the fuel tank within the airplane and the use of only a single, forward outlet line in Piper's auxiliary wing tanks, water and other fuel contaminants would not necessarily flow from the fuel tank to the fuel strainer with the airplane in its normal attitude on the ground. Ultimately, it became apparent that quick drains were needed, and in 1960 Piper incorporated them in the manufacture of Model PA-22 Tri-Pacer, tricycle-gear airplanes.

Piper Service Spares Letter No. 6 (SP-6), issued in February 1960, announced the availability of a wing fuel tank quick drain installation kit which could be installed on Piper Model PA-22 Tri-Pacer airplanes manufactured before that date and on Piper Models PA-11, PA-12, PA-18, PA-18A, and PA-20 series airplanes which incorporated a 1/4-inch-diameter tapered pipe fitting on the fuel tank. Piper currently receives only an occasional order for this kit. Modern Piper tricycle-gear airplanes such as the PA-28, PA-32, and PA-38, which routinely incorporate fuel tank quick drains, have relatively few accidents involving water in the fuel compared to the older Piper airplanes.

FAA Advisory Circular (AC) 20-43C, "Aircraft Fuel Control," indicates, based on water-in-fuel testing, that substantial quantities of water can remain in fuel even after an airplane's belly drain and fuel strainer cease to show any trace of water and that this residual water can be removed only by draining the fuel tank sumps. Therefore, the Safety Board believes that the FAA should issue an AD requiring the installation of quick drains on the wing fuel tanks of all airplanes affected by SP-6. The Safety Board also believes that Piper Models J-3 and PA-25 airplanes with fuselage fuel tanks, which are not affected by SP-6, should be retrofitted with fuel tank quick drains. These drains should be located at positions in the fuel system that will ensure the natural gravitational flow of water and other contaminants to the drain areas while the airplane is in the static, tail-low position on the ground.

The continued occurrence of a significant number of accidents involving water in the fuel also reflects a lack of pilot awareness in preventing, detecting, and eliminating water in the fuel. Consequently, the Safety Board believes that the FAA should prepare a comprehensive AC dealing exclusively with water-in-fuel problems. The AC should contain specific information regarding the detection and elimination of water from various types of airplanes and fuel systems. Other items that should be covered include: limitations of particular fuel systems relative to the drainage of water; special steps such as agitating the wings and lowering or raising the tail that should be taken during draining procedures; conditions such as prolonged outdoor storage, continued evidence of water in the fuel, drainage of a relatively large quantity of water, and other considerations that should merit purging of the airplane fuel system; visual inspection and leak test methods for checking fuel cap seals; and maintenance methods for both preventing and eliminating fuel system water. Publication of this new AC or its key elements in publications such as the FAA's "General Aviation News" and in the "Air Safety Journal" of the Air Safety Foundation of the Aircraft Owners and Pilots Association would be an excellent means of assuring that this important information is disseminated to all registered pilots. While the new AC is being prepared, the subject of water in the fuel and related maintenance and operational considerations should be emphasized in AC 43-16, "General Aviation Airworthiness Alerts." AC 20-43C, "Aircraft Fuel Control," and AC 00-34A, "Aircraft Ground Handling And Servicing," both refer to water in the fuel but only in a general and limited manner.

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

> Issue an Airworthiness Directive to require that rubberized bladder-type fuel cells in Cessna Models C-180, C-182, C-185, C-188, C-206, and C-207 be drained, purged, and swabbed to eliminate any water that may be entrapped within the cells. Other fuel system components, including fuel header tanks, carburetor bowls, fuel strainers, and fuel lines between the strainer and the low point of the fuel system, also should be drained at the same time. (Class I, Urgent Action) (A-83-3)

> Issue an Airworthiness Directive applicable to Cessna Models C-180, C-182, C-185, C-188, C-206, and C-207 equipped with rubberized bladder-type fuel cells to require that a fuel filler cap leak test in accordance wtih Cessna Owner Advisory SE 82-34A be conducted concurrently with the procedure in Safety Recommendation A-83-3 and subsequently on a periodic basis; if leakage is detected, require compliance with Cessna Service Letter SE 80-59. (Class I, Urgent Action) (A-83-4)

> Conduct an engineering evaluation of general aviation bladder-type fuel systems to determine the best means for improving the detection and elimination of water from these systems. Consideration should be given to bladder design features, installation procedures, and special system requirements. (Class II, Priority Action) (A-83-5)

> Require a fuel system modification to Cessna single-engine airplanes with rubberized bladder-type fuel cells which will provide a means for positive detection and/or elimination of water from the fuel, such as an increased capacity fuel strainer or a separate water collector system and quick drains at the low point of the fuel system. (Class II, Priority Action) (A-83-6)

Conduct an engineering evaluation of Cessna's flush plastic fuel caps to determine their sealing/venting characteristics ,under various critical service conditions, including extremes of temperature. If deficiencies are noted, appropriate corrective action should be required. (Class II, Priority Action) (A-83-7)

Issue an Airworthiness Directive to require the installation of wing fuel tank quick drains on all Piper PA-11, PA-12, PA-18, PA-18A, PA-20, and PA-22 airplanes in accordance with Piper Service Spares Letter No. 6. (Class II, Priority Action) (A-83-8)

Issue an Airworthiness Directive to require the installation of quick drains at appropriate locations on the fuselage fuel tanks of Piper Models J-3 and PA-25 airplanes. (Class II, Priority Action) (A-83-9)

Prepare and disseminate an Advisory Circular dealing exclusively with water-in-fuel problems. This circular should outline specific procedures for prevention, detection, and elimination of water in the fuel systems of various types of airplanes. (Class II, Priority Action) (A-83-10)

Emphasize on a recurrent basis in Advisory Circular 43-16, "General Aviation Airworthiness Alerts," the maintenance and operational considerations related to water in the fuel. (Class II, Priority Action) (A-83-11)

BURNETT, Chairman, GOLDMAN, Vice Chairman, and McADAMS, BURSLEY, and ENGEN, Members, concurred in these recommendations.

Patricia A. Goldman for

By: Jim Burnett
Chairman