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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ISSUED: December 4, 1979

Forwarded to:

Honorable Langhorne M. Bond
Administrator
Federal Aviation Administration
Washington, D.C. 20591

SAFETY RECOMMENDATION(S)

A-79-89 and -90

The National Transportation Safety Board has been investigating engine malfunctions and failures related to fuel line vapor problems in Cessna 200-series aircraft. The Federal Aviation Administration (FAA) Engineering and Manufacturing District Office (EMDO), which is responsible for oversight of Cessna Aircraft Company, and Cessna Aircraft Company personnel have been fully aware of our concern about this problem for some time. Cessna Aircraft Company recently issued service letters containing checklists and procedures on this subject to operators of Cessna 200-series aircraft. Additionally, the FAA issued an Airworthiness Directive (AD) 79-15-01, effective July 26, 1979, making the provisions of a portion of Cessna's service letters mandatory. Nevertheless, no action has been taken by Cessna or the FAA Central Region to institute hardware changes to correct this problem. The Safety Board is concerned about the lack of timely and adequate corrective action to eliminate fuel system problems that have been identified and believes that the FAA should take immediate action to eliminate the potentially unsafe condition on these aircraft.

The Safety Board's investigation of these Cessna 200-series aircraft engine malfunctions revealed that they frequently are caused by fuel vapor buildup in the aircraft and engine fuel system. Vapor generation in fuel systems is normal, but if it is not properly purged, or if vapor generation becomes excessive, fuel vapor will build up, restrict fuel flow, and may cause intermittent engine operation or complete loss of power. In some cases, the engine-driven fuel pump may cavitate, with an immediate total power loss.

The Safety Board became aware of fuel line vapor problems in the Cessna 200-series aircraft in April 1978, when one of its investigators experienced an engine malfunction while flying a 1974 turbocharged Cessna 210 (T-210). On two occasions, while level at 15,000 feet, the investigator noticed fuel

flow fluctuations and that the fuel flow dropped into the "red arc" 15 to 20 minutes after he switched from the right to left fuel tank. The investigator advanced the mixture to full rich, but there was no change in fuel flow indication, and actuation of the auxiliary fuel boost pump did not change the fuel flow indication appreciably. He noticed rough engine operation, and when he actuated the "maximum" electric fuel boost pump switch, the engine quit. After he released the "maximum" boost pump switch, the engine restarted and he made a safe landing. Apparently, the maximum boost pump purged the fuel vapor but "flooded" the engine.

At that time, the Safety Board believed that the problem with this aircraft was solved by compliance with Cessna Service Letter SE 77-38, dated October 4, 1977. SE 77-38 discussed symptoms similar to those experienced by the Safety Board's investigator. The letter stated that undersize fuel reservoir upper fittings had been installed in some Cessna 200-series aircraft and that the undersize fittings "may allow 'vapor buildup' in the fuel system by restricting purging of fuel vapor to the main tank." SE 77-38 recommended that, if certain fuel flow fluctuation symptoms were experienced, including "intermittent engine operation at altitude," the upper fittings should be inspected for proper size. If found undersize, the fuel reservoir should be replaced.

The left fuel reservoir upper fitting in the T-210 aircraft, in which the Safety Board's investigator encountered the engine problem, was inspected and found to be 0.016 inch undersize. The reservoir was replaced, and no further problems were reported with that aircraft. Review of Service Difficulty Reports and followup with Cessna and the Wichita EMDO revealed that there were several similar occurrences reported by operators which had led Cessna to issue SE 77-38.

During the Safety Board's investigation of a fatal Cessna T-206 accident in July 1978 in which an unexplained engine failure had occurred, we again became concerned about Cessna 200-series aircraft fuel system problems. Both fuel reservoir upper fittings in that aircraft were found to be considerably below specified tolerance. We concluded that fuel vapor buildup, as referenced in SE 77-38, may have caused the engine failure.

Because fuel vapor problems are extremely difficult to document and verify during an accident investigation, the Safety Board requested the Cessna Aircraft Company to test the fuel system in a full scale dynamic mockup of the Cessna 200-series aircraft. The purpose of the proposed test was to demonstrate and evaluate the mechanism of the suspected fuel vapor buildup and determine how the undersize fuel reservoir fittings caused problems.

A full scale fuel system mockup was constructed at Cessna Aircraft Company with various metering devices and transparent fuel supply lines and fuel reservoir. The mockup was considered by all parties to the investigation to be representative of the actual fuel system. The mockup was completed in January 1979, and numerous tests were accomplished in the presence of Safety Board, FAA, and Cessna personnel. Two findings were evidenced by manipulation of the mockup:

(1) During operation of the mockup to simulate various flight and power conditions, fuel vapor generated within the engine fuel system was returned to the reservoir via the engine-driven fuel pump vapor return line. The vapor collected in the upper neck of the reservoir and bubbled upward in the forward fuel supply line, located in the forward door posts, to the main tank, while fuel flowed down to the reservoir through both forward and aft lines, as designed. After an undersize fitting of the smallest dimension found in service was installed on the reservoir neck, vapor bubbles moved up the line to the tank. It was noted that a large bubble tended to hang at the top of the line in a bend where the line became horizontal to facilitate routing to the fuel cell. Apparently, the vapor bubbles lost their buoyancy as they were routed through the various bends and had to travel horizontally toward the fuel cell. Although the vapor bubbles seemed to lose energy en route to the fuel tank, they did in fact reach the tank and were vented overboard.

The findings of this portion of the test determined that an undersize fitting was not the reason for the fuel problems referenced in SE 77-38. When Cessna personnel were asked how they had previously determined that the undersized fittings were the reason for the problems, they replied that the fuel flow fluctuations and engine malfunctions reported by numerous pilots "suggested vapor buildup in the system." They said that undersize fittings were found in some aircraft and they, therefore, "concluded that the fittings were the reason." The Safety Board believes that the engineering evaluation, which was done to support SE 77-38, was inadequate and did not result in suitable corrective action for the reported problems.

(2) Since the reason for the reported fuel flow fluctuations and engine malfunctions had not been determined, further manipulation of the mockup was accomplished. After numerous tests, it was demonstrated that the mere act of switching the fuel tank selector from one tank to another could cause a condition in which fuel vapor was trapped in the reservoir and would eventually build up in the system between the reservoir and engine-driven fuel pump. This significantly reduced the fuel flow.

On certain occasions, when the fuel selector was switched, a surge of fuel started down the forward door post supply line. The fuel coming down the forward door post supply line was a solid column, flowing at the rate of demand required by the engine. The dynamics of the system in this condition were such that the column of fuel perpetuated itself in a "siphon-type" action. The aft supply line remained full of fuel, but no flow occurred. The flow of fuel down the forward supply line was sufficient to overcome the buoyancy of the fuel vapor bubbles and the vapor was trapped in the reservoir. Under these conditions, in 10 to 20 minutes, vapor nearly filled the reservoir and began to build up in the engine fuel system, and the fuel flow slowed. Symptoms of fuel flow fluctuations, similar to those experienced by the Safety Board's investigator and those reported by other pilots of this model aircraft, were evidenced on the metering devices of the mockup. This condition was induced and duplicated several times.

The findings of this portion of the test determined that vapor buildup problems in Cessna 200-series aircraft can be caused, in certain conditions, merely by the switching of fuel tanks. The symptoms occur approximately 10 to 20 minutes after switching fuel tanks. This condition will cause fuel flow fluctuations and may cause cavitation of the engine fuel pump with a subsequent loss of power. The Safety Board believes that the Cessna 200-series aircraft fuel system should be revised to prevent this problem.

The Safety Board is aware that many of the reported fuel flow fluctuation problems and unexplained engine failure/malfunctions in Cessna 200-series aircraft did not occur as a result of fuel tank switching. The Safety Board's investigation into this problem revealed that other design features of the fuel system and certain manufacturing practices can cause conditions conducive to fuel flow fluctuations and engine failure from vapor buildup in the system. Specifically, if excess heat is transmitted to the fuel system, considerable fuel vapor is generated within the system, and under certain conditions, fuel flow fluctuations and engine-driven fuel pump cavitation will occur. On certain turbocharged models, Cessna's manufacturing specifications require at least 1 inch clearance between the fuel line and the exhaust crossover pipe. However, several aircraft have been found, both in service and in production, with a clearance of less than 1 inch. Such proximity to a heat source can cause excessive fuel vaporization.

Routing and restrictions in the lines affect the purging of vapor when liquid is also present in the line. Vapor collects at high points in the line and at restrictions, such as tight bends with reduced tube diameter. During a recent investigation involving an engine failure in a new Cessna P-210, the Safety Board found that the forward fuel supply line from the tank in use had a bend with a radius of less than design specifications and a reduced tube diameter in the bend. In addition, the line was pitched downward between that bend and the fuel tank.

One positive means of eliminating vapor buildup in the aircraft and engine fuel systems is to route a separate vapor return line from the engine-driven fuel pump directly to the appropriate main fuel tank where the vapor will be vented overboard. The present design of the Cessna 200-series aircraft fuel system routes the vapor return line to the reservoir where the vapor must bubble in the forward fuel supply line to the tank. This design feature is not a positive means of venting vapor away and may not be in compliance with the intent of design certification provisions of Civil Air Regulation (CAR) 3.446 or Federal Aviation Regulation (FAR) 23.975 under which the Cessna 200-series aircraft were certificated. These regulations require that carburetors, 1/ which are provided with vapor elimination connections, be provided with a vent line which will lead vapors back to one of the aircraft's fuel tanks.

The Safety Board is aware that there is a difference of opinion between the FAA and Cessna regarding the compliance of the Cessna 200-series aircraft with CAR 3.446 and FAR 23.975. Nevertheless, the Safety Board believes that the Cessna 200-series aircraft fuel systems should be modified to prevent the

1/ "Carburetor" in this context has been interpreted by the FAA, for design certification purposes, to include fuel injection systems.

type of vapor problems evidenced. The vapor return line from the engine-driven fuel pump should be routed in a manner so as to provide positive vapor venting into the fuel tank. This is a typical practice in other fuel-injected general aviation aircraft, including twin-engine Cessna aircraft.

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

> Require the redesign of the Cessna 200-series aircraft fuel system to incorporate a separate means to route fuel vapor from the pump or reservoir to the fuel tanks, and require the retrofit of the new system on existing Cessna 200-series aircraft. (Class II, Priority Action) (A-79-89)
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> As an interim measure, issue an Airworthiness Directive to require the inspection of: (1) the forward fuel supply line for proper bend radius and tube diameter in the bend; and (2) the fuel lines inside the engine compartment for proper separation from exhaust system components or other heat sources of all Cessna 200-series airplanes, and the correction of all deficiencies found in those installations. (Class II, Priority Action) (A-79-90)

KING, Chairman, DRIVER, Vice Chairman, McADAMS, GOLDMAN, and BURSLEY, Members, concurred in these recommendations.

By: James B. King
Chairman