# United Flight 585 - Nov. 10, 1992 – Carl Vogt Acknowledgement Letter

***Editorial Note:***
On October 8, 1992, Boeing had a meeting to "Develop 737 Rudder PCU Retrofit Strategy." The meeting began with: "**We have a problem**." They stated that they did not have to ground the fleet, but they needed a retrofit program to fix the 737. The 737 servo valve jam had a potential for reversal and it did not meet the "Fail-Safe" Design Intent. Their goal was to develop consensus on a retrofit plan to present to the V.P.'s of Boeing. They discussed four options and ultimately acted on the retrofit that took the longest (8 years), but was less costly. It appears from meeting notes that they decided not to request a new Airworthiness Directive, but rather requested meetings with "key regulatory agencies."

I believe the following letter of November 10, 1992, was a result of that highly confidential Boeing meeting. Carl Vogt wrote the letter before the December 8, 1992, NTSB meeting when United 585 was discussed, and the NTSB Board Members wrongly voted that UA585 was the “wind” or “not solved.”

The following letter from Carl Vogt, NTSB Chair at that time, states, *"that the potential for rudder reversal could exist in all B-737 main rudder PCU's."* Boeing and Parker-Hannifin had agreed to proceed with the design changes to fix the rudder design problem on the Boeing 737.

Some of the most important language in this letter was not in the December,1992 Final Report which primarily blamed the wind for the fatal crash. The Revised Final Report, which stated that the probable cause was the rudder failure, was issued June 5, 2001, ten (10) years after United 585.

## National Transportation Safety Board
## Washington, D.C. 20594
## Safety Recommendation

**Date: November 10, 1992**

**In reply refer to: A-92-118 through-121**

Honorable Thomas C. Richards
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On July 16, 1992, during a check of the flight controls in a United Airlines (UAL) Boeing 737-300, while taxiing to takeoff from Chicago-O'Hare International Airport, the captain discovered that the airplane's rudder pedal stopped at around 25-percent left pedal travel. The airplane returned to the gate and the main rudder power control unit (PCU) was removed.

The PCU was tested at UAL's maintenance facilities in San Francisco, California, on July 20, 1992. During that testing, the PCU operated in an anomalous manner. Under certain conditions, the actuator piston would move in a direction opposite to the commanded and intended input. However, during other demonstrations, the PCU operated normally.

As a result of the initial observations, the unit was taken to the facilities of Parker Hannifin, the valve manufacturer, at Irvine, California, for further testing by Boeing, Parker Hannifin, and UAL. Test results showed that the dual concentric servo valve installed on the main rudder PCU could, under some circumstances; result in motion opposite to that commanded by the rudder pedals. Boeing and Parker Hannifin then initiated a design review to better understand the nature of the reversal, to develop a design change to preclude the reversal, as well as a plan to implement the design change.

On July 30, 1992, the Safety Board became aware of the taxi incident at Chicago and the subsequent investigation of the PCU. Testing and design change efforts are continuing, and Safety Board specialists have participated in these efforts.

**During subsequent testing of the rudder PCU, anomalous actions, ranging from sluggish movement of the actuator piston to full reversal in the commanded direction of piston travel, were observed when the input crank was held against the PCU body stops and the yaw damper piston was in the extend position. High internal fluid leakage was also noted**. The capability of the PCU to produce force to move the rudder against aerodynamic loads was not measured. The interaction of the yaw damper and the PCU operation as observed is not fully understood. In addition, it is unknown whether the yaw damper was commanding rudder movement at the time that the UAL captain performed the rudder control check. During the tests, it was noted that lower hydraulic operating pressures aided in achieving anomalous actions. Tapping on the dual servo valve body or actuator summing levers prompted the PCU to return to normal operation. Releasing the force on the input crank also returned the PCU to normal operation.

In normal operation, the pilot applies force to the input crank through the rudder pedals. If the pilot releases pressure on the pedal when a direction reversal occurs, the tests show that the PCU should return to normal operation. However, it is highly unlikely that pilots would respond to a rudder reversal by releasing pedal pressure. If, as is for more likely, rudder pressure is held until the rudder has reversed position, the centering unit may supply sufficient force to the input crank to sustain the anomalous condition even though pedal pressure is released.

**Analysis by Boeing and Parker Hannifin shows that the potential for rudder reversal could exist in all B-737 main rudder PCUs. The internal stops of the dual concentric servo valve can allow the secondary slide of some valves to overtravel under some conditions**. Normally, the primary slide moves about 0.045 inches before the secondary slide moves. If the primary slide is pinned or jammed to the secondary slide, control inputs resulting in the normal movement of the primary slide can lead to the overtravel of the secondary slide. If the overtravel of the secondary slide is sufficient, hydraulic fluid could be routed through a flow passage located outside the normal valve travel range that **could result in piston (and rudder) motion in the direction opposite to the input command**.

According to Boeing and Parker Hannifin, the effects of an overtravel condition of the secondary slide would not be apparent during approved acceptance tests. Accordingly, one part of the acceptance test was modified to facilitate the investigation. During this rest, the primary and secondary slides were pinned together to prevent relative motion and were moved through an extended range of motion, as allowed by the internal secondary stops. This range of motion is greater than the normal range of motion of the secondary slide. As the overtravel progressed, the valve porting moved out of normal range, and the pressure and return porting to the respective slides of the actuator piston were interconnected and eventually reversed. The initial effect was excessive internal leakage. Full movement of the slide produced a 3,000 pounds per square inch (psi) reversed pressure drop across the actuator piston with the leakage slowed.

Boeing and UAL have developed a field test procedure to verify the proper operation of the dual servo valve. A total of 212 UAL B-737 airplanes were checked. One main rudder PCU was removed as a result of "hissing" sounds during part of the test. The source of these sounds was attributed to minor leakage in the PCU that was not associated with the dual servo valve. The unit passed acceptance tests and could have been returned to service. There were no other indications of abnormally operating PCUs during the fleet-wide checks. Tests and design analysis indicate that the anomalous operation will occur only when a unique condition prevents independent movement of the primary and secondary slides of the servo valve (a condition that could develop suddenly or occur intermittently). Thus, a onetime check may not ensure that reversal will not occur.

The dual servo valves removed from the B-737s that crashed in Colorado Springs, Colorado on March 3. 1991, and in the Darien Province of Panama on June 6, 1992, were also tested. The results show that a 50 percent pressure drop could have developed on the Colorado Springs unit if a failure mechanism produced an overtravel of the secondary valve slide. As understood thus far, if such a pressure drop occurred, the main rudder PCU could only develop 50 percent of the rudder hinge moment capability, working in the proper direction. The pressure drop would be similar to losing either A- or B redundant hydraulic systems. Moreover, the results show that a complete pressure drop, without reversal, could have developed on the Panama unit only if a failure mechanism produced an overtravel of the secondary slide valve. The unit would lose hinge

moment capability, but movement of the rudder in the opposite direction beyond neutral would not occur.

Boeing aerodynamic data for the B-737-200 airplane shows that full rudder deflection (approximately 26 degrees) may be uncontrollable with full control wheel deflection (approximately 107 degrees) under certain conditions. Flap position and airspeed are important when determining controllability during full rudder deflection.

Historical maintenance data shows that there have been five other incidents related to the main rudder PCU. It is believed that two of them were detected in flight.

**On July 24, 1974**, the flight crew of a: B-737 reported that the rudder moved "full right" on touchdown. The investigation revealed that the primary and secondary control valves were stuck together by a shot peen ball lodged in the valve.

**On October 30, 1975**, the flight crew of a B-737 reported that the rudder pedals moved to the right "half-way" and then jammed. This action was repeated three times and then corrected by cycling the rudder with the standby rudder system. Further examination indicated that the system was contaminated by metal particles.

Another report on **October 20, 1975**, indicated that during a PCU inspection a jammed control valve was found. 'The data associated with this report is insufficient to determine the cause of the PCU removal.

On **August 31, 1992**, a B-737 reported that the rudder "locked up" on approach and that the flight crew initiated a go-around and activated the standby rudder system. The landing was uneventful. The examination of the PCU revealed internal contamination and worn seals. It was suspected that high leakage from the worn seals resulted in the PCU having a limited capability to generate enough force to move the rudder.

On **November 8. 1990**, during an overhaul, a PCU was found to have internal corrosion. The primary slide was stuck at neutral to the secondary as a result of corrosion. There were no reports of malfunction prior to the disassembly.

Boeing and Parker Hannifin are currently developing design changes to the dual servo valve that would limit the travel of the secondary slide to eliminate the potential for pressure and return porting reversal. The Safety Board understands that the rudder PCUs would most likely be returned to Parker Hannifin for modification. Newly defined tolerances would require that parts from the dual servo valve be selectively fit and/or modified to produce acceptable test results. Boeing is planning a retrofit program.

More than 3,000 B-737 main rudder PCUs have been produced. The unit is not a high replacement item that requires large numbers of spares. At this time, only one test fixture is known to exist, and only one facility is prepared to implement the changes. The Safety Board understands that a significant period of time may be required to remove, overhaul, and return to service all rudder PCUs in the B-737 fleet.

The Safety Board recognizes that the B-737-series airplanes have flown about 50 million flight hours, providing safe transportation to the public. Only two confirmed airborne incidents have resulted from rudder operational anomalies, and these did not result in injury to passengers or damage to the airplanes. Nonetheless, the Safety Board believes that rudder malfunctions, as described in this letter, could present significant flight control difficulties under certain circumstances, for example, sudden, large rudder pedal inputs in response to an engine failure during initial climb. Therefore, the Safety Board believes that interim precautionary measures are warranted, pending completion of the long-term PCU overhaul and replacement program.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:
Require that Boeing develop a repetitive maintenance test procedure to be used by B-737 operators to verify the proper operation of the main rudder power control unit servo valve until a

design change is implemented that would preclude the possibility of anomalies attributed to the overtravel of the secondary slide. (Class 11, Priority Action) (A92-118)

Require that Boeing develop an approved preflight check of the rudder system to be used by operators to verify, to the extent possible, the proper operation of the main rudder power control unit servo valve until a design change is implemented that would preclude the possibility of rudder reversals attributed to the overtravel of the secondary slide. (Class II, Priority Action) (A-92-119) Require operators, by airworthiness directive, to incorporate design changes for the B-737 main rudder power control unit servo valve when these changes are made available by Boeing. These changes should preclude the possibility of rudder reversals attributed to the overtravel of the secondary slide. (Class 11, Priority Action) (A-92-120)

Conduct a design review of servo valves manufactured by Parker Hannifin having a design similar to the B-737 rudder power control unit servo valve that control essential flight control hydraulic power control units on transport- category airplanes certified by the Federal Aviation Administration to determine that the design is not susceptible to inducing flight control malfunctions or reversals due to overtravel of the servo slides. (Class II, Priority Action) (A.92-121)

Chairman VOGT, Vice Chairman COUGHLIN, and Members LAUBER, HART, and HAMMERSCHMIDT concurred in these recommendations.

*By: Carl W. Vogt*
*Chairman*