# 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

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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 far 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 inch 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

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