NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594
September 3, 1997

ERRATA SHEET TO OCTOBER 24, 1996
SYSTEMS GROUP CHAIRMAN'S FACTUAL REPORT OF INVESTIGATION

A. ACCIDENT DCA-94-MA-076

Location: Aliquippa, Pennsylvania
Date: September 8, 1994
Time: 1904 Eastern Daylight Time
Aircraft: Boeing 737-300, N513AU

The following changes should be made to the report dated October 24, 1996. Deletions are noted as a strike through. Additions are noted as bold italic type within brackets. Page numbers refer to original page number of text.

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Another test was conducted to simulate the rudder system effects of ~~introducing~~ ***[the manual insertion of]*** a foreign object or block between the main rudder PCU input crank and the PCU manifold body stop. Testing indicated that with the crank movement blocked, a sustained left yaw damper command caused the rudder to travel to its limit. With the block moved to the other side of the crank arm, a sustained right yaw damper command caused the rudder to travel to its limit. The movement in either case could not be stopped until the blocking material fell from its position between the body stop and the input crank ***[when the yaw damper signal was returned to zero, the rudder returned to neutral]***. In some cases rudder pedal input in the direction of the rudder movement resulted in the blocking material falling free whereby rudder control was regained.

[The purpose of inserting a foreign object between the input link and manifold stop was to demonstrate the direction of pcu/rudder motion. Testing by the systems group at Ogden had already demonstrated that a sustained yaw damper input combined with the blockage would result in full rudder deflection].

[The test demonstrated that for a left rudder deflection, a foreign object would have to jam against the aft stop. It was observed that with the PCU installed in the airplane, that the PCU linkage (H link) prevented a foreign object from dropping into the space between the stop and the linkage. It was also observed that the orientation of the PCU would make it difficult for a foreign object to lodge between the forward stop and input link. When the yaw damper signal was removed with the object lodged in the stop, the rudder returned to center.]

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Condition B1.39.0935.201 involved applying 50 lbs. load to the R_b cable. There was no rudder deflection. Condition B1.39.0935.202 involved applying 100 lbs. load to the R_b cable. There was no rudder deflection. Condition B1.39.0935.~~203~~ ***[.205]*** involved applying 150 lbs. load to the R_b cable. The rudder deflected 2.1°. Condition B1.39.0935.203 involved applying ~~200~~ ***[250]*** lbs. load to the R_b cable. The rudder deflected 3.2°. Condition B1.39.0935.206 involved applying 200 lbs. load to the R_a cable. The rudder deflected 1.07°. Condition B1.39.0935.207 involved applying 250 lbs. load to the R_a cable. The rudder deflected 2.28°.

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Condition B1.39.0935.101 recorded the cutting of the rudder cable. A ~~load~~ ***[loud]*** "bang" was heard as the cable was cut at body station 360; the rudder did not move. Condition B1.39.0935.102 recorded the end positions of the rudder cables after the cut. Condition B1.39.0935.103 recorded the rudder operation after the cable cut.

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After the preceding tests, the standby rudder actuator was replaced with a standby actuator capable of ~~fixing~~ ***[binding]*** the actuator input shaft at variable ~~positions~~ ***[force levels].*** The objective of the tests were to determine the effects of different levels of binding at the standby rudder actuator input shaft and bearing interface.

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With 100 lbs of binding force, the rudder could travel 8° to the left or right with a full left or right yaw damper command, respectively. A force of 60 lbs on the left rudder pedal would restore the rudder to the neutral position. A force of 30 lbs on the on the right rudder pedal would restore the rudder to the neutral position. ***[The 30 lb force indicated that the binding force dropped during the course of the testing.]*** Disabling the A hydraulic system had negligible adverse effect on the rudder system operation.

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The actuator was used to test the effects of hard jamming of the input shaft and bearing at the standby rudder actuator neutral position, the standby rudder actuator input arm position for a 3° ***[yaw damper]*** ~~rudder~~ input, and the standby rudder actuator input arm position for a full maximum rate rudder input limited by the main rudder PCU external manifold (body) stop.

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The following test sequence was performed to examine the effects of hard binding/jamming of the standby rudder actuator input arm at the position it would be in for a full +3° (left) ~~rudder input command from the main rudder PCU~~ ***[yaw damper command]:***

The following test sequence was performed to examine the effects of hard binding/jamming of the standby rudder actuator input arm at the position it would be in for a full -3° (right) ~~rudder input command from the main rudder PCU~~ ***[yaw damper command]***:

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With the standby rudder actuator input shaft bound at 3° (full yaw damper command capability) left, the rudder could travel 10° to the left with a full left yaw damper command and 3° to the right with a full right yaw damper command. ***[With the yaw damper at its full deflection]*** a force of ~~25~~ *[95]* lbs or ~~95~~ *[25]* lbs on the appropriate rudder pedal, respectively, would restore the rudder to the neutral position. With a jam at the full left yaw damper position and no yaw damper commanded input, the rudder went 2° left of neutral position.

With the standby rudder actuator input shaft bound at 3° (full yaw damper command capability) right, the rudder could travel 2° to the left with a full left yaw damper command and 13° to the right with a full right yaw damper command. ***[With the yaw damper at its full deflection]*** a force of ~~110~~ *[30]* lbs or ~~30~~ *[110]* lbs on the appropriate rudder pedal, respectively, would restore the rudder to the neutral position. With a jam at the full right yaw damper position and no yaw damper commanded input, the rudder went 4° right of neutral position.

With the standby rudder actuator input shaft bound at a position it would be in for a full maximum rate rudder input (to the left) limited by the main rudder PCU external manifold (body) stop, the rudder went 19° left of neutral position*[.]* ~~with a full yaw damper command. With a full yaw damper command input to the main rudder PCU~~, A force of 65 lbs restored the rudder to the neutral position. ~~A force of 140 lbs was required to restore the rudder to neutral without any yaw damper command~~. ***[The force on the standby PCU input arm for the condition was 140 lbs.]***

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A standby rudder actuator input shaft and bearing were manufactured by Boeing with ~~controlled tolerances~~ ***[reduced clearances]*** to "naturally" induce galling after ***[extended cycling]*** ~~several cycles of operation~~. After galling the shaft and bearing, the binding forces were measured as approximately 60 lbs. The input shaft and bearing were then installed into a standby rudder actuator and installed into the test airplane. The standby rudder actuator could not be pressurized after modification.

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A second standby rudder actuator input shaft and bearing were manufactured by Boeing with sufficiently ~~controlled tolerances~~ ***[reduced clearances]*** to "naturally" induce galling after ~~several cycles of operation~~ ***[extended cycling].*** After galling the shaft and bearing, the binding forces were measured as approximately 60 lbs. The input shaft and bearing were then installed into a standby rudder actuator and installed into the test airplane. The standby rudder actuator differed from the actuator previously discussed in section 3.5 in that it could be pressurized.

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A test was conducted to simulate the rudder system effects of introducing a foreign object or block between the main rudder PCU input crank and the PCU manifold body stop.

The following test sequence was performed:

1. A ~~piece of folded paper was~~ ***[business card was folded 3 times and]*** inserted between the manifold body stop and input crank arm.

2. The A and B hydraulic systems were powered.
3. A left yaw damper hardover command was input to the main rudder PCU.
4. The rudder pedal was pushed to release the blockage.
5. A right yaw damper hardover command was input to the main rudder PCU.
6. The rudder pedal was pushed to release the blockage.

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<u>3.7.1 Rudder system effects of jamming foreign materials test results summary</u>

Testing indicated that with the crank movement blocked, a sustained left yaw damper command caused the rudder to travel to its limit. Likewise with the block moved to the other side of the crank arm, a sustained right yaw damper command caused the rudder to travel to its limit. The movement in either case could not be stopped until the blocking material fell from its position between the body stop and the input crank. ***[When the yaw damper input signal was returned to zero, the rudder surface returned to neutral].*** ~~In some cases~~ ***[R]***udder pedal input in the direction of the rudder movement resulted in the blocking material falling free and rudder control was regained.

[redacted]

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PRO 9/3/97