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WASHINGTON, D.C.

POWERPLANT GROUP CHAIRMAN'S FACTUAL REPORT - ADDENDUM B

by

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NATIONAL TRANSPORTATION SAFETY BOARD
OFFICE OF AVIATION SAFETY
WASHINGTON, D.C.

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POWERPLANT FACTUAL REPORT - ADDENDUM B

DCA94MA076

A. ACCIDENT

LOCATION:	Aliquippa, Pennsylvania
DATE:	September 8, 1994
TIME:	1904 Eastern Daylight Time
AIRPLANE:	USAir, Boeing 737-300, Flight 427, N513AU

B. GROUP

Jerome D. Frechette Group Chairman	National Transportation Safety Board Washington, D.C.
Mario L. Giordano	Federal Aviation Administration Coraopolis, Pennsylvania
Stephen Bray	FAA Transport Aircraft Directorate Northwest Region, Seattle, Washington
Clifford M. Schjoneman	The Boeing Commercial Airplane Group Seattle, Washington
Robert Wilson	The Boeing Commercial Airplane Group Seattle, Washington
Steve Slagle	The Boeing Commercial Airplane Group Seattle, Washington
Robert A. Halsmer	USAir Pittsburgh, Pennsylvania
John D. Long	USAir, Air Line Pilot's Association Baltimore, Maryland

Mike Gardner	International Association of Machinists and Aerospace Workers, South San Francisco, California
Michael C. Lindamood	Aviall Dallas, Texas
Tom Redick	Dowty Aerospace Duarte, California
Richard Hansen	Dowty Aerospace Duarte, California
Al Boza	Dowty Aerospace Duarte, California

C. SUMMARY

The cylinders and actuator rods of all four locking actuators fractured at a plane coincident with the base of the actuator piston. The head end of the actuators, which included the lock mechanism and the actuator pistons were examined. The four hydraulic actuator locking heads were shipped to the NTSB, Seattle, Washington office from Washington, D.C., on October 13, 1994, under the direction of the National Transportation Safety Board. The locking heads were hand-carried to the Boeing Company, Renton, Washington for X-ray inspection on October 17, 1994. The locking heads were later boxed and hand-carried to Dowty Aerospace, Duarte, California for the disassembly on October 19, 1994.

The inspections revealed that all four locking heads were impact and heat damaged. All four actuator pistons were in the "stowed" position, and the locking keys were engaged (locked position) with the pistons. Three of the four lock sleeves were in the "locked" position and one lock sleeve (No. 2 engine-inboard side), was in the "unlocked" position. According to the Dowty Aerospace and Boeing Engineers observing the teardown, the witness and wear marks inside the four locking heads were consistent with normal operation.

During disassembly of the No. 2 engine-inboard side actuator, the lock sleeve was stuck in the unlocked position and required force in excess of the lock sleeve spring force to remove. The manual unlock handle had been separated from the spindle and the locking head housing was deformed. Visual inspection of spindle revealed it fractured in overload and dimensional inspection of the housing revealed the housing was deformed approximately 0.040 inches, front to rear.

D. DETAILS OF THE INVESTIGATION

The four hydraulic actuator locking heads were tagged with the installation location from the accident airplane when removed from the shipping container. Each locking head was engraved with its installation location with a vibro-tool before disassembly.

1. LOCKING HEAD DESCRIPTION

The thrust reverser consists of two translating sleeves with three hydraulic actuators per sleeve. The upper hydraulic actuators have lock mechanisms to prevent reverser deployment without the application of hydraulic pressure. The lock mechanism has a spring-loaded lock sleeve, and three keys, which engage a groove in the actuator piston. The application of hydraulic pressure moves the lock sleeve against the spring force, releasing the three keys, mechanically unlocking the actuator. The actuator can also be manually unlocked for maintenance by actuation of the handle located on the forward end of the housing. Manipulation of the handle rotates a spindle and a smaller lever that moves the lock sleeve into the unlocked position.

The locking head housing has "deploy" and "stow" hydraulic pressure ports, antirotation bolt hole, and a manual unlock mechanism boss. A feedback rod extends out the front of the housing and the actuator cylinder extends out the rear of the housing and is held in position with a glandnut. Rotation of the lock sleeve and cylinder Is prevented by the antirotation bolt.

Each of the three actuators on each translating sleeve contains a lead screw within the cylinder and an angle drive that are interconnected with flexible synchronization shafts. The flexible drive shaft resides within the hydraulic lines that also interconnect the actuators. During deployment, hydraulic pressure is applied simultaneously to all actuators on both sleeves. The actuators extend and the interconnected lead screws rotate (driven by the translating pistons), matching the extension rate of the three actuators, preventing jamming of the translating sleeve. There is no flex cable interconnection between the inboard and outboard thrust reverser translating sleeves.

2. LOCKING HEAD DISASSEMBLY AND INSPECTION

The X-ray images revealed that all four locking head pistons were in their stowed position with the keys engaged with their respective pistons prior to disassembly. Three lock sleeves were in the locked position and one lock sleeve was in the unlocked position. The lock sleeve on the No. 2 engine, inboard side, locking head was in the unlocked position.

All four locking head actuators were heat and impact damaged. The hydraulic tubing, flex shafts, rigging brackets, and feed back rods were impact damaged and either cut or torn from their respective attachment point. All four actuator cylinders and actuator rods were separated from their respective housing at the glandnut location, exposing the aft face of each piston head. The feedback rods were cut in the Dowty machine shop to ease disassembly.

The positions of the piston heads and the lock sleeves were determined by dimensional inspection. The deformation of the locking head housings were also measured. The distances from a datum to the piston heads and lock sleeves were measured and compared to the nominal value on the blueprint. The center of the "extend" hydraulic pressure port was the datum. Dimension A is the distance from the datum to the flange on the lock sleeve, inside the boss for the manual unlock mechanism. Dimension B is the distance from the datum to the rear face of the piston head. The measurements were made with a coordinate measurement machine (CMM). The blueprint distance from the datum to the lock sleeve, in the locked position, is 4.018 $\pm$ 0.040 inches. The blueprint distance from the datum to the rear face of the piston head is 3.7797 $\pm$ 0.069 inches. The blueprint distance of the lock sleeve stroke, from locked to unlocked, is 0.2447 $\pm$ 0.050 inches.

The deformation of the housing was measured in two perpendicular planes, tangential and radial to the engine's longitudinal axis, by locating the center of the housing at one end and comparing it to the center at the opposite end. The forwardmost location was the center at the manual unlock lever, and the rearmost location was the center at the actuating cylinder glandnut. The deformation measured in the radial plane, dimension C, was the perpendicular distance from the centerline of the housing at the manual unlock lever spindle compared to the center of the glandnut. The blueprint distance of the spindle bushing center to the housing centerline was 0.885-0.875 inches. The deformation in the tangential plane, dimension D, was the centerline of the housing between the machined flats at the unlock lever compared it to the center of the glandnut. The blueprint described the centerline at the manual unlock lever and the glandnut as the same line. Dimensions A, B, C, D and the difference from the nominal blueprint (B/P) value, in inches, are shown below:

LOCKSLEEVE AND PISTON POSITIONS FROM DATUM RELATIVE TO NOMINAL BLUEPRINT

	DIMENSION A (B/P 4.018 $\pm$ 0.040)	DIMENSION B (B/P 3.7797 $\pm$ 0.069)	DIMENSION C (B/P 0.885-0.875)	DIMENSION D (B/P 0.00)
		ENGINE No. 1		
Outboard	4.040	3.679	0.864	0.00
Difference	(0.022)	(0.1007)	(0.016)	
Inboard	4.039	3.707	0.864	0.0015
Difference	(0.021)	(0.0727)	(0.014)	

ENGINE No. 2

Inboard	4.241	3.673	0.868	0.003
Difference	(0.233)*	(0.1067)	(0.012)	
Outboard	4.021	3.730	0.875	0.025
Difference	(0.003)	(0.0497)	(0.005)	

* The lock sleeve stroke distance from locked to unlocked is 0.2447 $\pm$0.050 inches.

The four locking head actuators were disassembled following the dimensional inspection.

2.1 Engine No. 1, Inboard Side

The antirotation bolt was difficult to turn during removal. Visual inspection of the antirotation bolt revealed the shank was bent approximately 10° perpendicular to the longitudinal centerline of the housing. Witness marks were on the side of the bolt shank in the direction of the bend. The witness marks were larger and deeper when compared to the marks on the antirotation bolts from the other locking head actuators. Additionally, witness marks were found on the longitudinal edge of the antirotation slots in the lock sleeve and cylinder, in line with the antirotation bolt hole.

The piston and lock sleeve assembly remained in place following removal of the glandnut. The piston and lock sleeve assembly was pressed out and in the locked condition. The lock sleeve spring was in serviceable condition. The "O" ring on the cylinder was in serviceable condition. The lock sleeve and piston were separated. The lock keys were wet with oil and free to move within their respective key slot. According to the Dowty and Boeing engineers participating in the examination, the lock keys, and piston were in serviceable condition and the wear marks were from normal operation.

2.2 Engine No. 1, Outboard Side

The piston and lock sleeve assembly remained in place following removal of the glandnut. The piston and lock sleeve assembly was pressed out and in the locked condition. The lock sleeve spring remained compressed following removal of the lock sleeve. The internal components were heat damaged, and covered with a hard, black substance. The lock keys were forcibly removed from their respective key slot. According to the Dowty and Boeing engineers participating in the examination, the wear marks on the lock keys, and piston were from normal operation.

2.3 Engine No. 2, Inboard Side

The piston and lock sleeve assembly remained in place following removal of the glandnut. The piston and lock sleeve were pressed out separately. The lock sleeve was galled on the outer diameter of the flange where the sleeve meets the stem. The lock sleeve spring was in serviceable condition. The "O" ring on the cylinder was in serviceable condition and wet with fluid. The lock keys were free to move within their respective key

slot and the piston follower was free to move under spring force. According to the Dowty and Boeing engineers participating in the examination, the lock keys, and piston were in serviceable condition and the wear marks were from normal operation.

An additional measurement of the actuator housing was made, following the removal of the internal components, to determine why the lock sleeve was held in the unlocked position inside the housing. The additional measurement was made to reveal any additional deformation forward of the manual unlock mechanism. The perpendicular distance from the center of the forward most bore to the center of the rearmost bore was measured at approximately 0.040 inches. The weight of the lock sleeve was measured at 8 ounces.

2.4 Engine No. 2, Outboard Side

The piston and lock sleeve assembly remained in place following removal of the glandnut. The piston and lock sleeve assembly was pressed out and in the locked condition. The internal components were heat damaged, and covered with a hard, black substance. The lock keys were forcibly removed from their respective key slot. According to the Dowty and Boeing engineers participating in the examination, the wear marks on the lock keys, and piston were from normal operation.

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Jerome D. Frechette,
Powerplant Group Chairman

12/12/94