Docket No.: **SA-510**
Exhibit No.: **9B**

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Metallurgist's Factual Reports
95-42 Standby Rudder Input Shaft
95-43 Rudder Pedal Assemblies

NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

December 16, 1994

METALLURGIST'S FACTUAL REPORT — Report No. 95-42

A. ACCIDENT

Place	: Aliquippa, Pennsylvania
Date	: August 8, 1994
Vehicle	: Boeing 737-3B7, N513AU
NTSB No.	: DCA 94-M-A076
Investigator	: Gregory Phillips, AS-40

B. COMPONENTS EXAMINED

Standby rudder actuator components: input shaft, P/N 1087-23; bearing, P/N 1087-22, thrust (needle) bearing race.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted components from the standby rudder actuator is shown in figure 1. Arrow "IS" in this figure indicates the input shaft, arrow "B" indicates the bearing, and arrow "R" indicates the race.

Input Shaft

A schematic illustration of the input shaft and its position inside the bearing is shown in figure 2. Land 1 is isolated from Land 2 by a Teflon seal. Inboard from this seal (Land 1), the shaft is lubricated by hydraulic fluid; outboard from the seal (Land 2), the shaft is not lubricated.

Examination showed that the surface of the shaft in Land 1 contained two distinct bands of galled metal[1]. Areas of galling were located roughly opposite to each other across the diameter of the shaft and are shown by arrows "a" and "b" in the two photographs of figure 3.

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[1]Galling is defined as a condition in which microscopic projections or asperities bond at the sliding interface under very high local pressure. Subsequently, the sliding forces fracture the bonds, tearing metal from one surface and transferring it to the other.

Measurements indicated that the galled areas extended through an arc of about 60 degrees at the location denoted by arrow "a" in this figure and through an arc of about 50 degrees at the location denoted by arrow "b". Examination also revealed that galling band "a" had a greater total width and a greater built-up of material compared to galling band "b".

Figure 4 contains three scanning electron microscope photographs depicting the typical appearance of the galling on the surface of the shaft at progressively higher magnifications. An energy dispersive X-ray analysis (EDS), performed on the surface of the shaft in an area not affected by the galling produced a spectrum consistent with the specified 440C stainless steel (see top spectrum in figure 5). EDS spectra generated in the galled areas (see bottom spectrum in figure 5) contained a chromium peak that was about 2/3 the height of the chromium peak in the spectrum from the unaffected areas of the shaft. Spectra from the galled areas were consistent with a type 416 stainless steel specified for the bearing.

The diameter of the shaft, measured in several different locations, averaged 0. 6128 inch in Land 1 and 0.6101 inch in Land 2. In 1986, revision "G" to the shaft engineering drawing No. 1087-23 was introduced reducing the Land 2 diameter from 0.613 inch to 0.610 inch. The diameter of Land 1 had remained unchanged. Measurements showed that both diameters were within the range currently specified. Examination revealed no evidence of galling on Land 2 of the shaft.

Bearing

Examination of the bearing bore revealed the two shallow cavity areas corresponding in orientation, size, and shape to the two areas on the shaft that contained deposited metal. Figure 6 depicts a lateral view of the bearing showing the axial location of galling by the unmarked arrow. The two photographs in figure 7 are close-up oblique views of the bearing bore illustrating the appearance of the galled areas: the left photograph corresponds to the galled area on the shaft denoted by arrow "a" in figure 3, and the right photograph corresponds to the galled area denoted by arrow "b". The longitudinal marks (arrows "d" in figure 7) and circumferential marks (arrows "c") found in the galled area appeared to be secondary damage which had been produced during the extracting of the shaft from the bearing. Figure 8 shows the hexagonal head of the bearing (looking inboard on the shaft-bearing assembly) and the head of the shaft (looking outboard on the assembly). Arched arrows "a" and "b" in this figure denote the circumferential extent of the areas of galling in both parts.

The diameter of the bearing bore averaged 0.61372 inch. The EDS analysis of the bearing material produced a spectrum consistent with the specified 416 stainless steel.

Thrust Bearing Race

Examination of the submitted bearing race (see figure 9) revealed a non-uniform roller contact pattern. In the area indicated by the curved arrow "r", the roller contact appeared to be lighter than on the rest of the race surface.

[redacted]

Jean Bernstein
Metallurgist

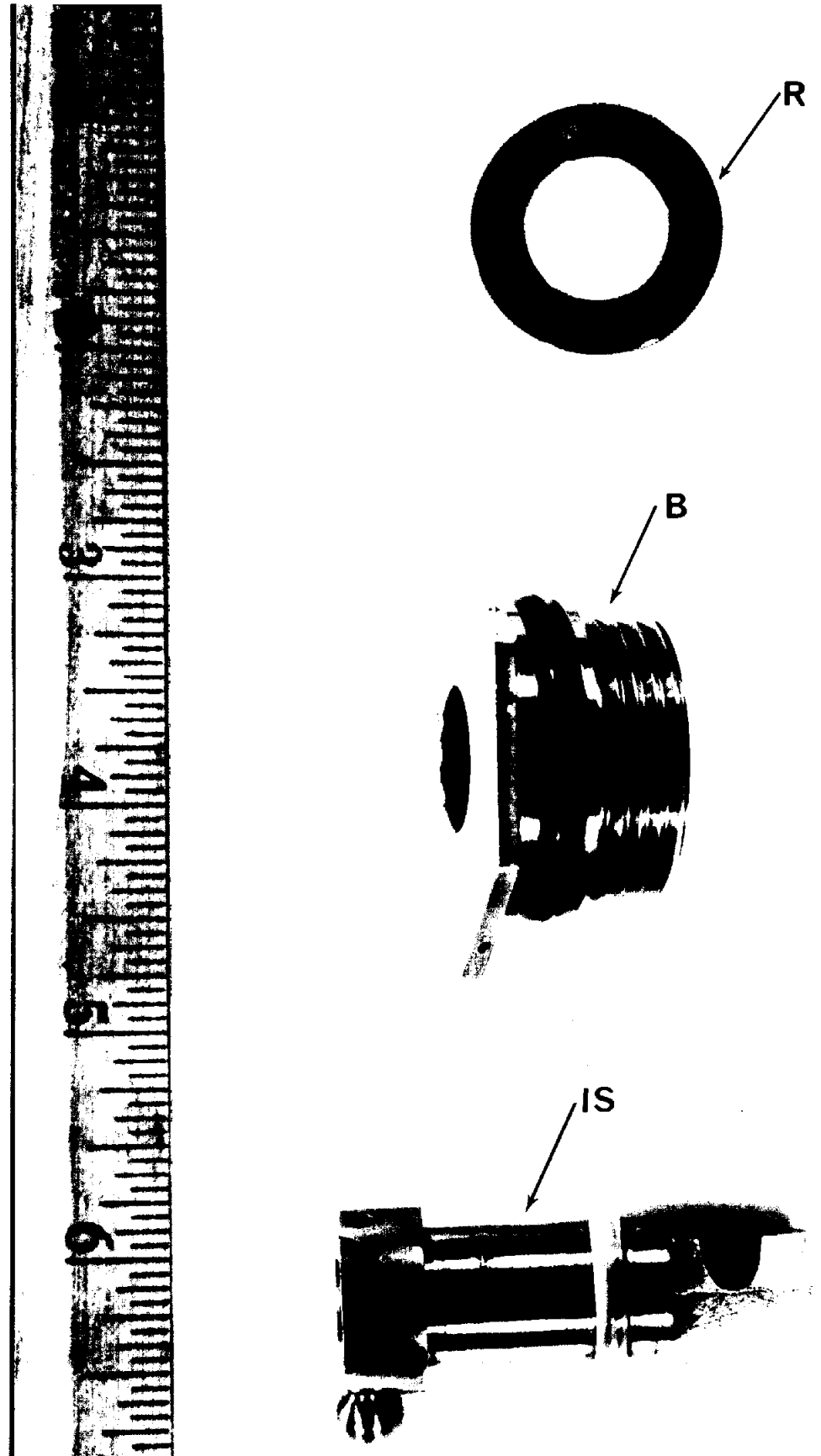


Figure 1: Overall view of the as received components: Arrow "IS" denotes the input shaft, arrow "B" - the bearing, arrows "R" - the race.

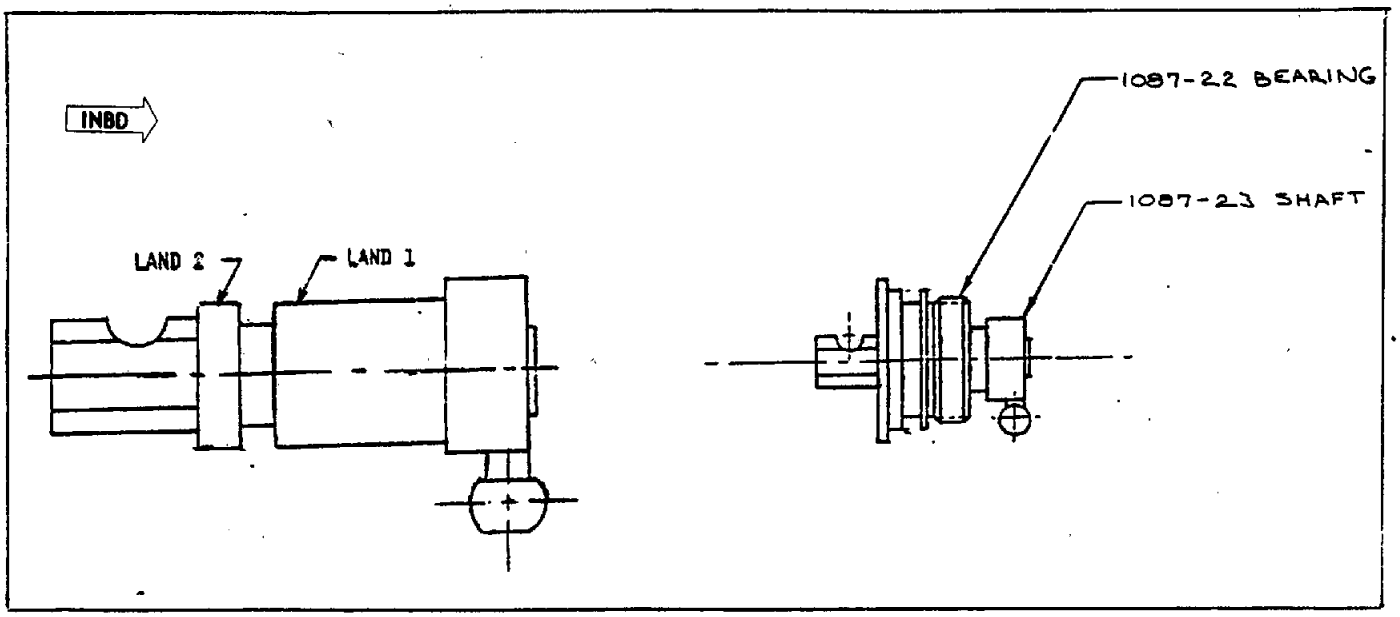


Figure 2: Schematic illustration of the input shaft and its position inside the bearing.

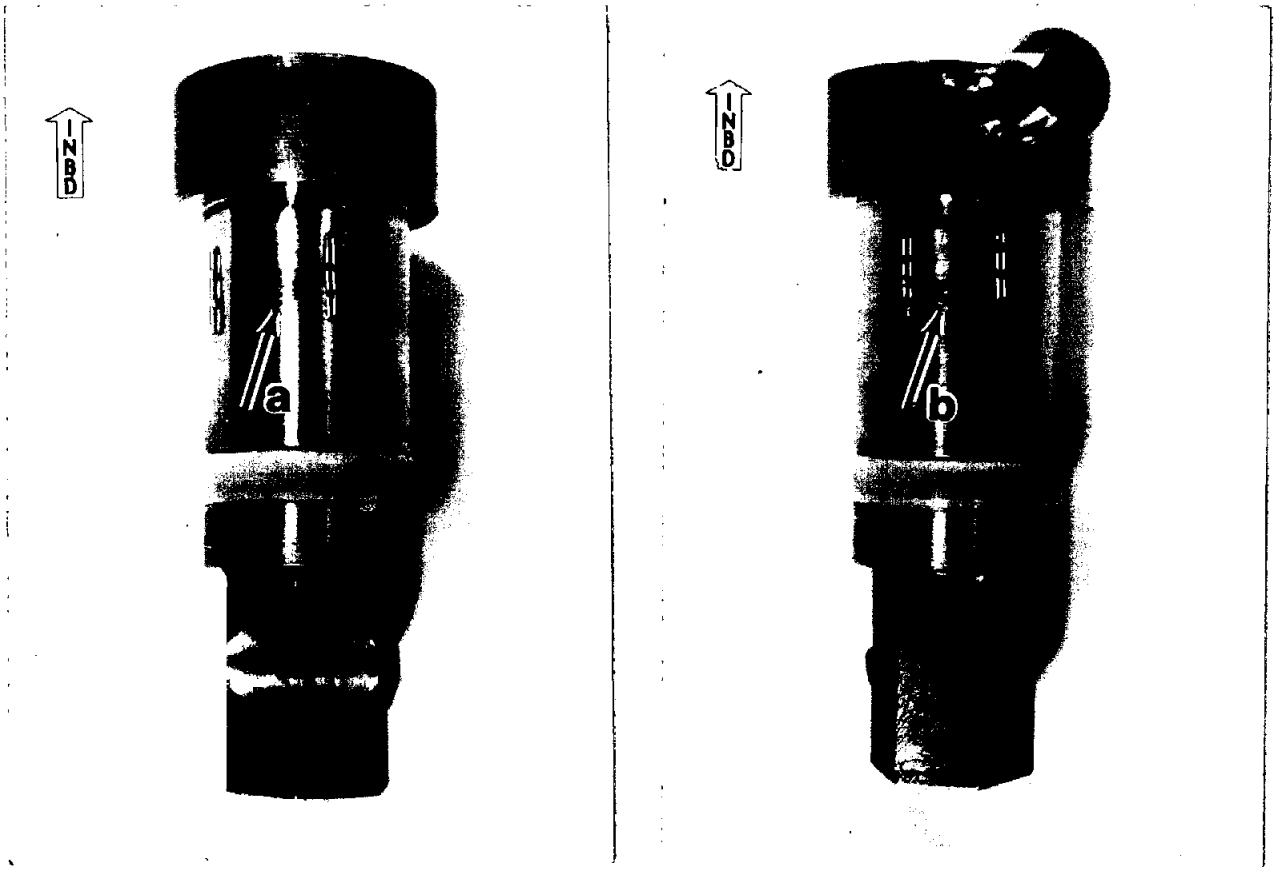
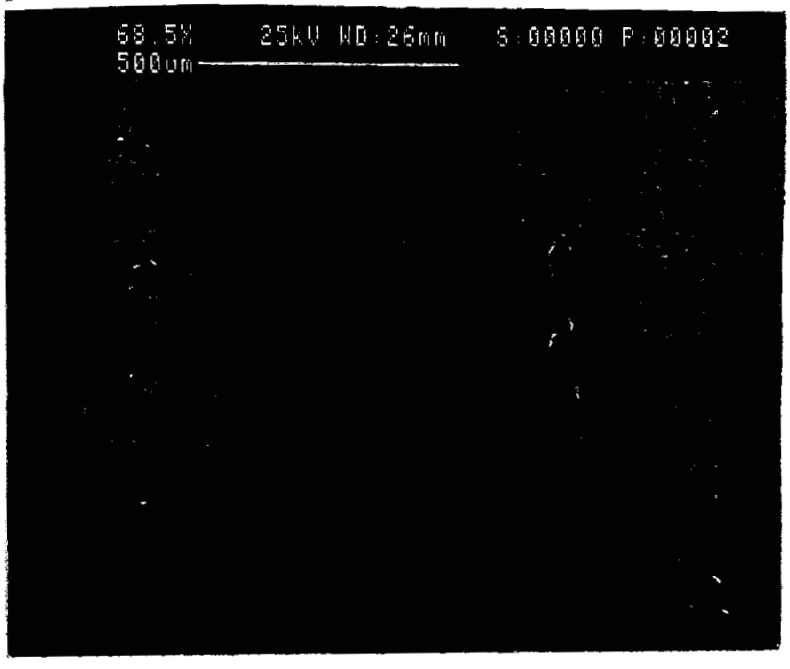
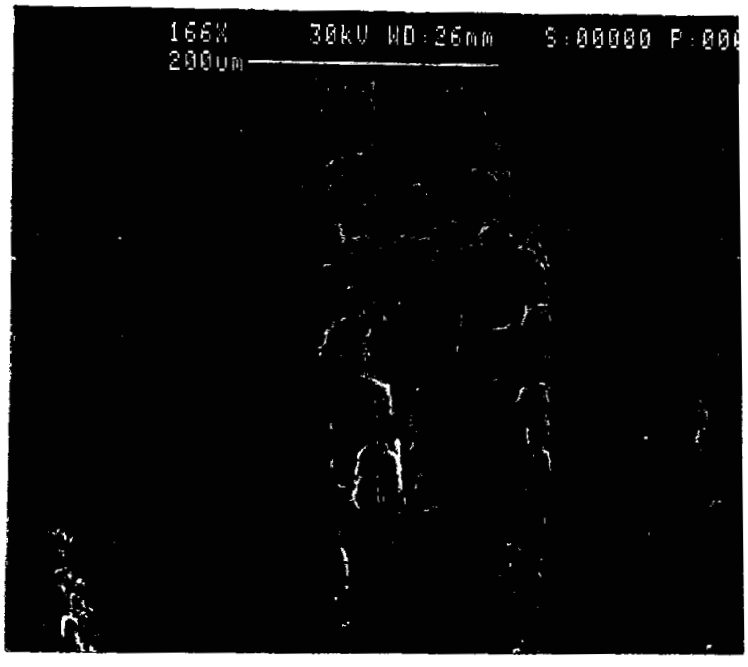


Figure 3: Appearance of the galled areas (arrows "a" and "b") on the surface of the shaft. Magnification 2X.





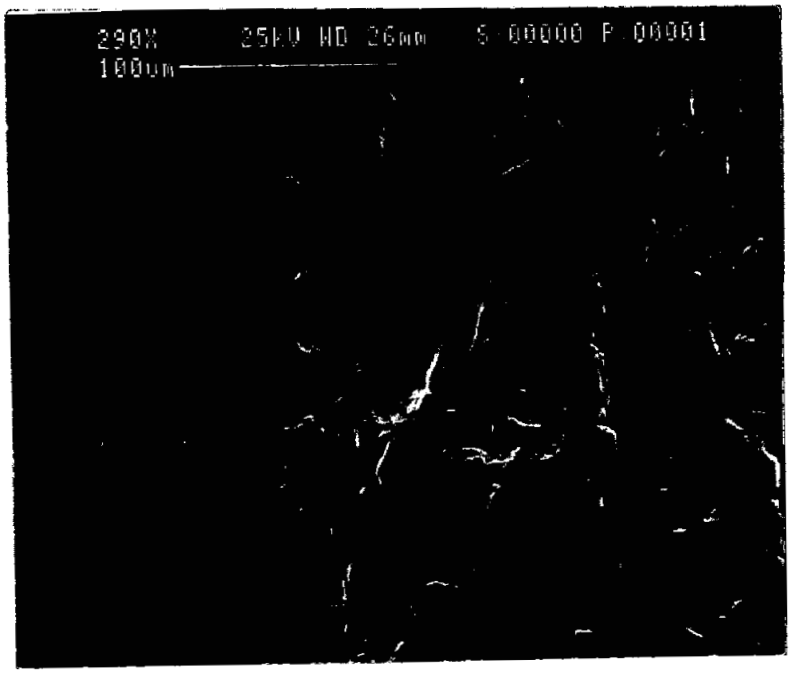


Figure 4: Typical appearance of the galled areas on the surface of the shaft, as shown at progressively higher magnifications.

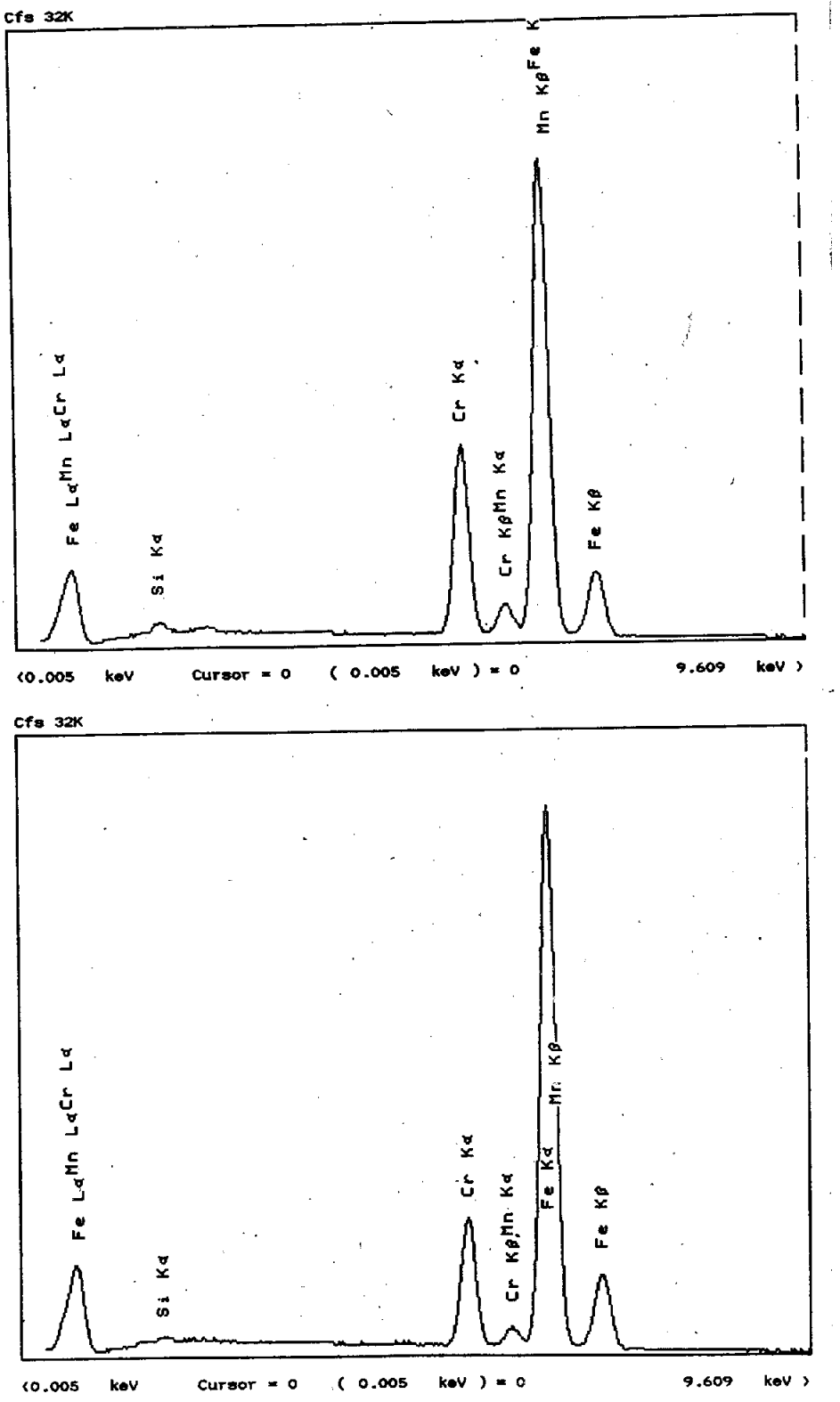


Figure 5: EDS spectra produced on the undamaged area of the shaft (top spectrum) and the galled area (bottom spectrum).

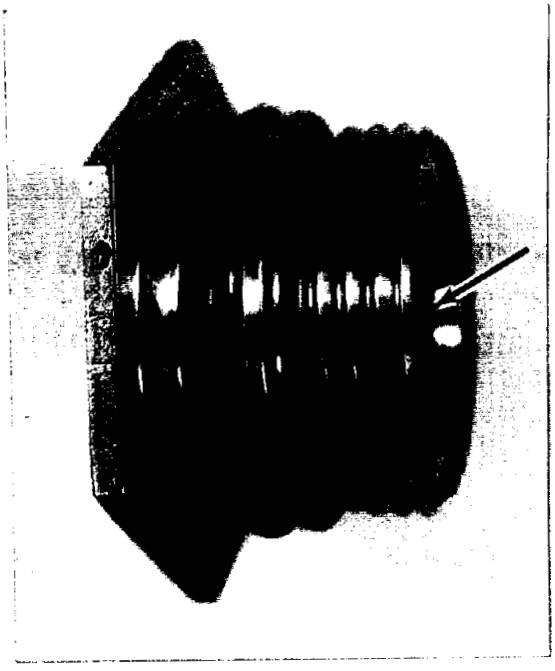


Figure 6: A view of the bearing showing the location of galling on the bearing bore by the unmarked arrow. Magnification 2X,

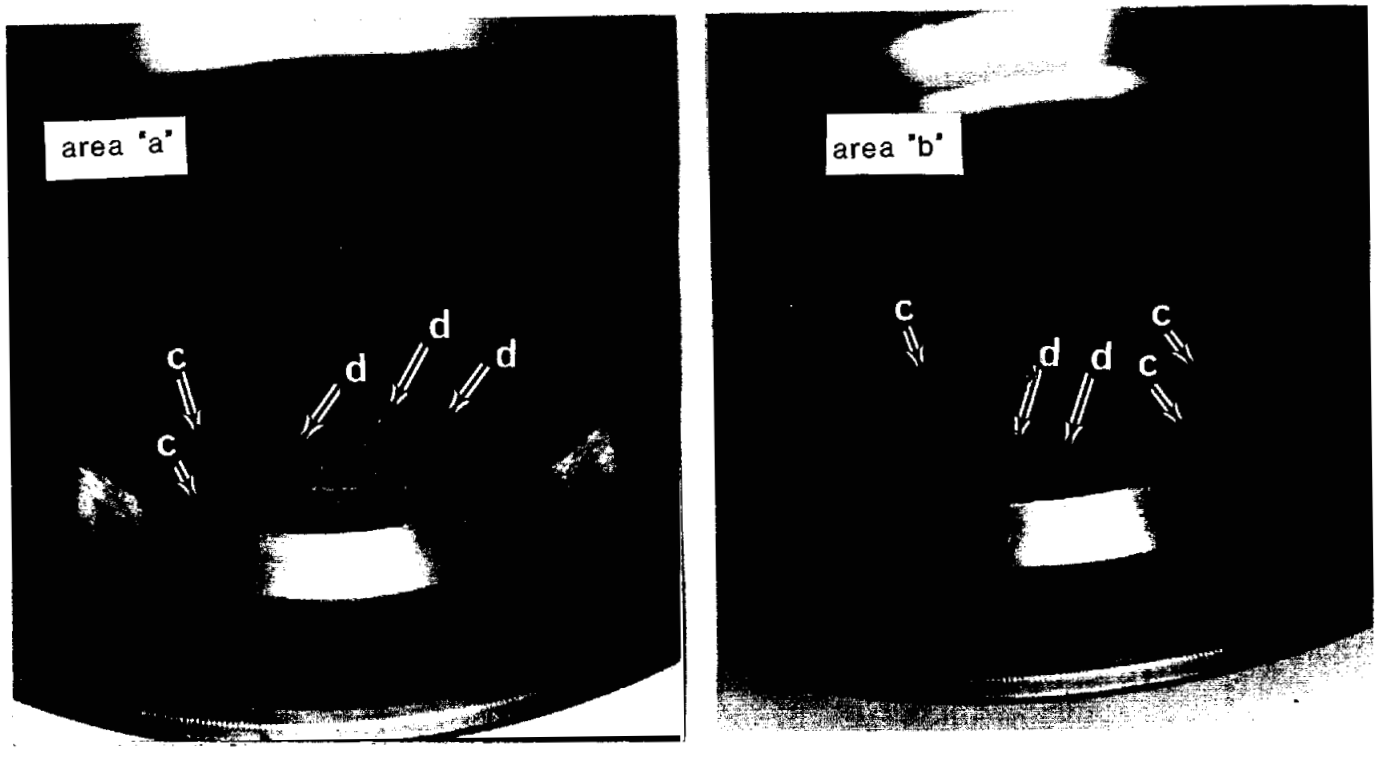


Figure 7: Close-up oblique views of the galled areas on the surface of the bearing bore. Arrows "d" and "c" denote secondary scoring. Magnification approximately 5X.

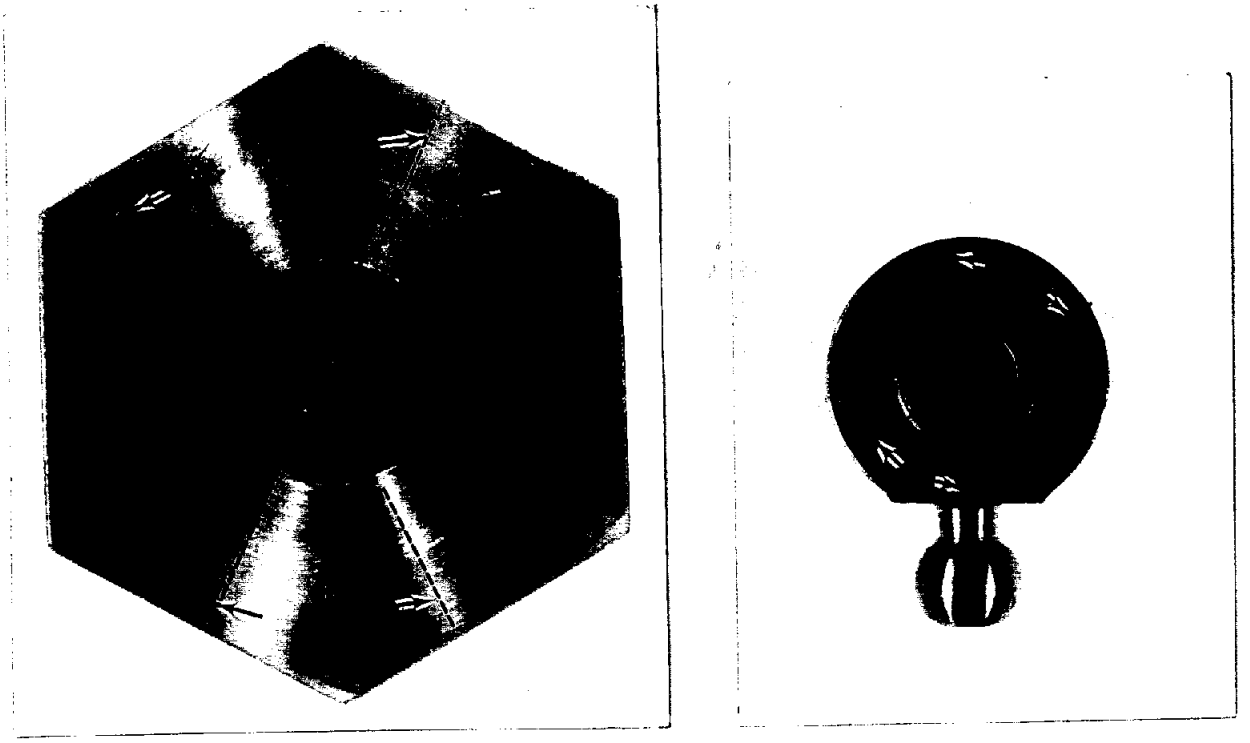


Figure 8: Locations of the galling damage projected on the hexagonal head of the bearing (left photograph) and the head of the input shaft (right photograph). Magnification 2X.

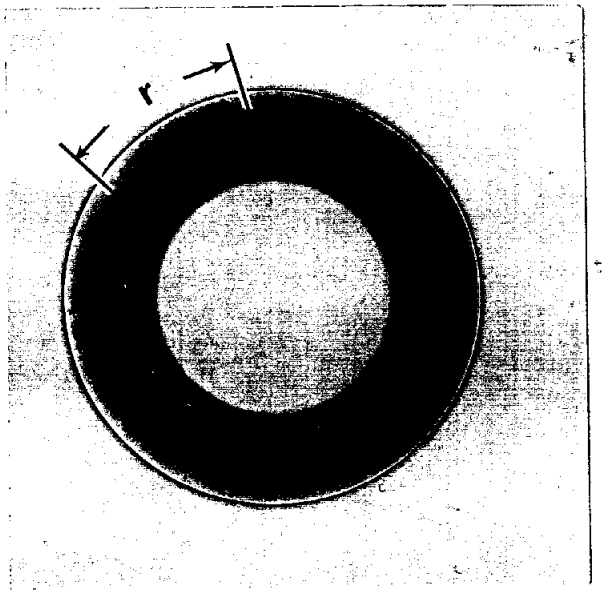


Figure 9: Needle rollers contact pattern on the submitted thrust bearing race. Magnification 2X.

(10)

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December 27, 1994

METALLURGIST'S FACTUAL REPORT — Report No. 95-43

A. ACCIDENT

Place	: Aliquippa, Pennsylvania
Date	: September 8, 1994
Vehicle	: Boeing 737-3B7, N513AU
NTSB No.	: DCA94-M-A076
Investigator	: Greg Phillips (AS-40)

B. COMPONENTS EXAMINED

Pilot and Copilot Rudder Pedal Assembles

C. DETAILS OF THE EXAMINATION

The pilot and copilots rudder pedal assemblies were visually examined in the Equipment Quality Analysis laboratory (EQA) of Boeing Commercial Airplane Group on December 8th, 1994. The rudder pedal assemblies were fragmented and heavily distorted. In addition, the portions of the copilots assembly had been exposed to the post impact fire.

The left pedal pivot lug on both the pilot's and copilot's assemblies were fractured near their respective support tubes as shown in figures 1 and 2. The pivot lugs are held stationary in the upper ends of the support tubes and allow the pedals to pivot and articulate during brake application and pedal movement. Optical examinations of the fracture faces with a bench binocular microscope revealed features typical of bending overstress fractures on both pivot lugs. The fracture features also indicated the direction of bending for each lug with respect to the support tubes. The bending directions for the pedals are denoted by the large arrows in figures 1 and 2. With the support tubes oriented vertically, both pedal lugs were bent in the forward and slightly down directions at the time of separations.

The right pedal lug on both assemblies remained attached to the support tubes but were bent. Again with respect to vertically positioned support tubes, the right pedal lug on the pilot's assembly was belt forward and down and the copilot's right pedal was bent forward and up.

for [redacted]
Joe Epperson
Senior Metallurgist

Figure 1 A side view of the pilot's fractured left rudder pedal pivot lug. The direction of bending is indicated by the large arrow.

Figure 2 A side view of the copilot's fractured left rudder pedal pivot lug. The direction of bending is indicated by the large arrow.