Docket No.: SA-510
Exhibit No.: 9N

NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C.

Metallurgist's Factual Report
95-54 Servo Valve s/n 2956 Examination

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

January 4, 1995

METALLURGIST'S FACTUAL REPORT — Report No. 95-54

A. ACCIDENT

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

B. COMPONENTS EXAMINED

1) Rudder main power control unit servo valve P/N 68010-5003, S/N 2956 from the accident airplane obtained from Gregory Phillips on 10/20/94.

2) Primary and secondary spools S/N's 425X, 2023, 3223, 3226, and 3228 obtained from representatives at Parker Hannifin on 11/3/94.

3) Primary and secondary spools S/N 4375 (indicated as being new) obtained from Gregory Phillips 12/12/94.

4) Primary spool S/N 2720 (indicated as being trimmed and no wipe) and primary spool S/N 984X (indicated as being trimmed and wiped) obtained 12/13/94 from Steve Weik representing Parker Hannifin.

C. DETAILS OF THE EXAMINATION

Background

Preliminary detailed examination of the accident airplane's primary and secondary spools and other spools obtained at Parker Hannifin (see items 1 and 2, in section B above) was performed without party representation during the examination. However, on November 2 and 3 and again on December 12 through 14, 1994, further examination of the accident servo valve and the remaining parts listed (items 3 and 4, above) was performed with the following party representatives present:

Craig Dickerson
Lead Engineer, Fracture Analysis Materials and Processing Engineering
Boeing Commercial Airplane Group
Seattle, Washington

Paul J. Cline
Design Engineer, 737/757 Flight Controls, Renton Division
Boeing Commercial Airplane Group
Seattle, Washington

Steve Weik
Sr. Design Engineer, Control Systems Division
Parker Hannifin Corporation, Parker Bertea Aerospace
Irvine, California

Preliminary Detail Examination of Accident Servo Valve S/N 2956

Figure 1 shows an overall view of the S/N 2956 servo valve after disassembly in the laboratory. As disassembled, the primary and secondary spools were examined with the aid of a bench binocular microscope for evidence of damage to the metering edges on the outside diameter of the primary and secondary spools (areas indicated by unmarked brackets in figure 1). Small areas indicative of chipping of the nitrided case were noted on the primary spool on two of the lands[1] adjacent to the metering edge. However, examination disclosed no evidence of distortion or deformation to the metering edges.

In order to more closely examine the spools, each was separately viewed with the aid of a scanning electron microscope (SEM). The primary spool was rinsed in a gentle stream of alcohol and subsequently blown dry before placing in the SEM. The metering edges and lands adjacent to the metering edges were then systematically examined at magnifications from X500 to X2000 looking for evidence of distress to the metering edge/land or evidence of material transfer onto the lands.

On the primary spool the chipped areas of the nitrided case were clean of debris and showed no evidence of material smear or transfer onto the land. The size of the largest chip-out of the case was about 150 microns (0.006 inch) circumferentially by about 50 microns (0.002 inch) longitudinally. The depth of all chip-outs was very shallow compared to their length and width. However, sporadic areas were found where material appeared to be smeared over the metering edge and onto the land. Typical examples of this smearing are shown in figure 2. The smearing in all cases appeared to be thin with extension longitudinally onto the land only about 10 microns (0.00039 inch) from the metering edge. Energy dispersive X-ray (EDX) spectra of the smear produced characteristic peaks identical to spectra of the primary non-smear land indicating the material smear was the same as the spool (required spool material is Nitroloy 135 with a nitrided case depth of 0.005 to 0.008 inch).

SEM examination of the secondary spool metering edge / lands disclosed no chipping or evidence of smeared material onto the lands.

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[1]Outside diameter of the spool in the area of the metering edges.

Primary and Secondary Spools S/N's 425X, 2023, 3223, 3226, and 3228

For comparison purposes primary and secondary spools S/N's 425X, 2023, 3223, 3226, and 3228 were obtained from representatives of Parker Hannifin. These spools were reportedly removed during overhaul and were no longer to be used in assemblies. The service time on the spools was not known.

Examination of these spools was limited to bench binocular viewing using magnifications up to approximately X75. Some of the primary spools showed evidence of small shallow chip-outs at the metering edge similar to those found on the accident primary spool. The metering edges of all the spools were similar in appearance to the edges of the accident spools.

Primary and Secondary Spools S/N 4375 Indicated As Being New

The primary and secondary spools S/N 4375 were identified as being removed from an in-stock new rudder power control unit at Boeing. SEM examination of the primary spool disclosed material smears similar in shape, extent, and chemical composition (as found by EDX spectra) to those found on the primary spool of the accident airplane. Examples of these material smears are depicted in figure 3. Also found were small chip-outs of the nitrided case land adjacent to the metering edge.

Primary Spools S/N 2720 and S/N 984X

During original manufacture the servo valve spools are trimmed and burr wiped and functionally tested in matched assemblies. Trimming is the process in which the groove/land edges on the spools are abrasively cut to a different longitudinal position. A thin rotating abrasive wheel is positioned into the land at the edge of the groove to the approximate depth of the groove while the spool is rotating in a lathe. This results in one side of the groove being cut to a new longitudinal position, moving the metering edge longitudinally. Subsequent to the trimming operation the spool is burr wiped by placing the spool in a machine that polishes the outside diameter of the spool.

Two primary spools were brought to the laboratory on December 13, 1994 by Steve Weik. One of the spools, S/N 2720, was reportedly re-processed to an intermediate condition in the manufacturing that would show an as- trimmed surface at the metering edge. The other spool, S/N 984X, was similarly trim processed but was subsequently burr wiped.

SEM examination of the as-trimmed spool disclosed numerous burrs of the trimmed (metering) edge as shown in figure 4. These burrs are folded over metal that are curled over the land at the trimmed edge of the spool. Such burrs were sporadically found around the circumference of the trimmed edge. Examination of the trimmed and burr wiped spool showed areas on the land adjacent to the trimmed edge (about the same magnitude as the burrs on the as-trimmed spool) that appeared to be flattened down and smoothed over.

Examples of these are displayed in figure 5. EDX analysis of the flattened and smoothed over material gave a spectrum nearly identical to the spool material.

Inside Diameter Inspection of Secondary Spool and Housing

The inside diameters of the secondary spool and housing contain an assembled stack of components that contain holes and rectangular shaped windows for the flow of hydraulic fluid. During assembly and operation of the servo valve the windows are in the immediate proximity to the metering edges of the spools. At the Parker Hannifin facilities in Irvine, California these windows were viewed at magnifications of about X200 using the borescopic equipment used during the trimming operation in production. These windows were later examined with the aid of a bench binocular microscope up to X37 magnification utilizing an inclined mirror situated in the bores. Also, replica tape impressions that were sputter coated with gold/palladium were made of the stack surfaces adjacent to the windows in the housing and examined with the SEM. All of the above examinations of the windows disclosed no evidence to indicate that there were deformations of or smeared metal adjacent to any of the window edges.

[redacted]

Michael L. Marx
Supervisory Metallurgist
Chief, Materials Laboratory Division

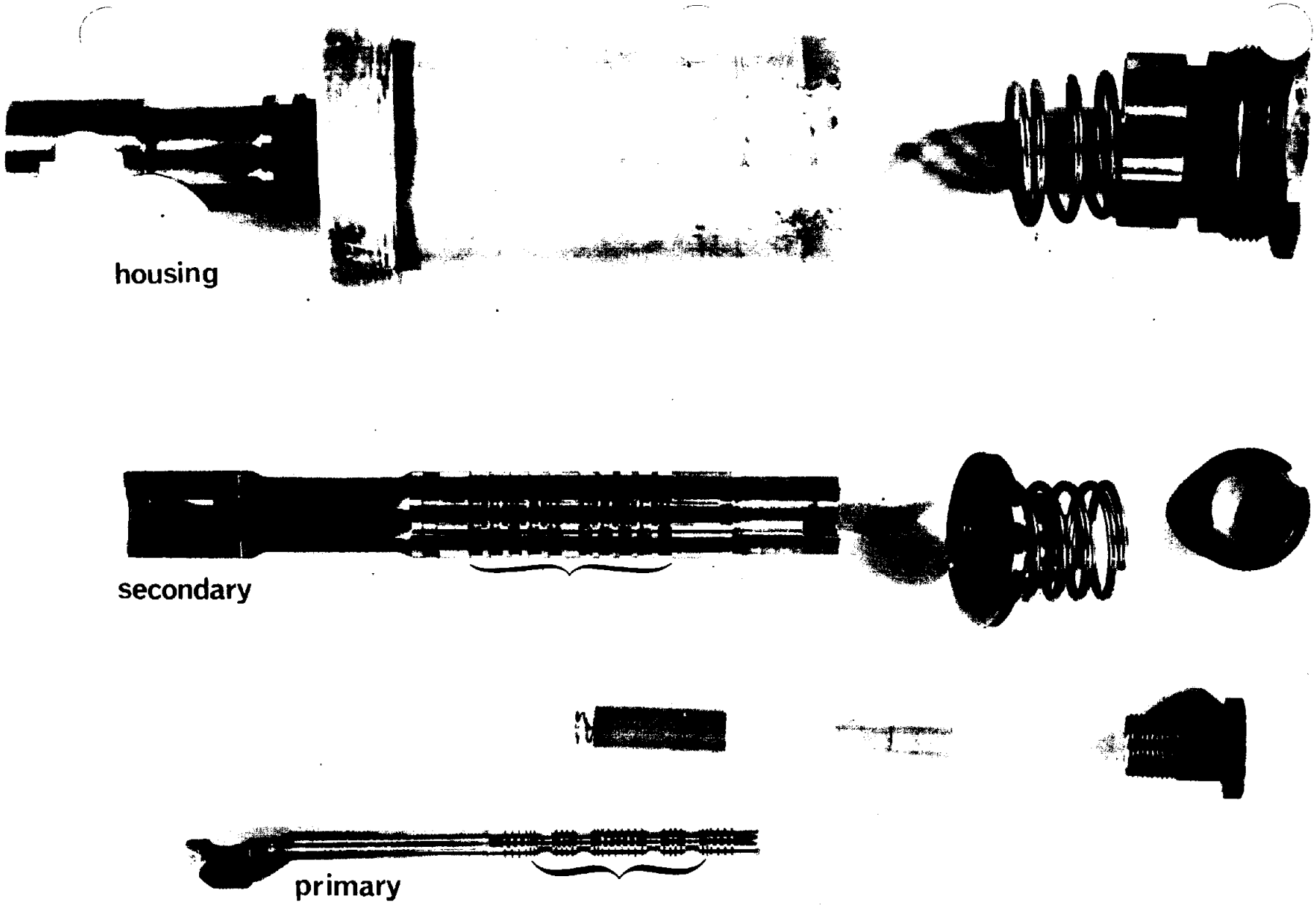
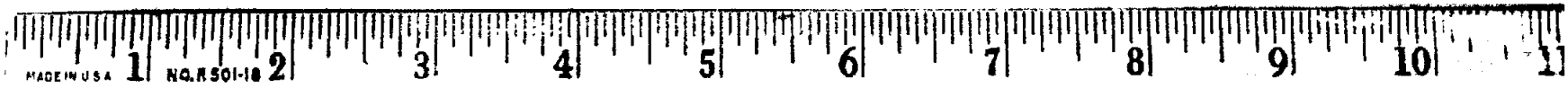


Figure 1. Overall view of the components of the S/N 2956 servo valve after disassembly.



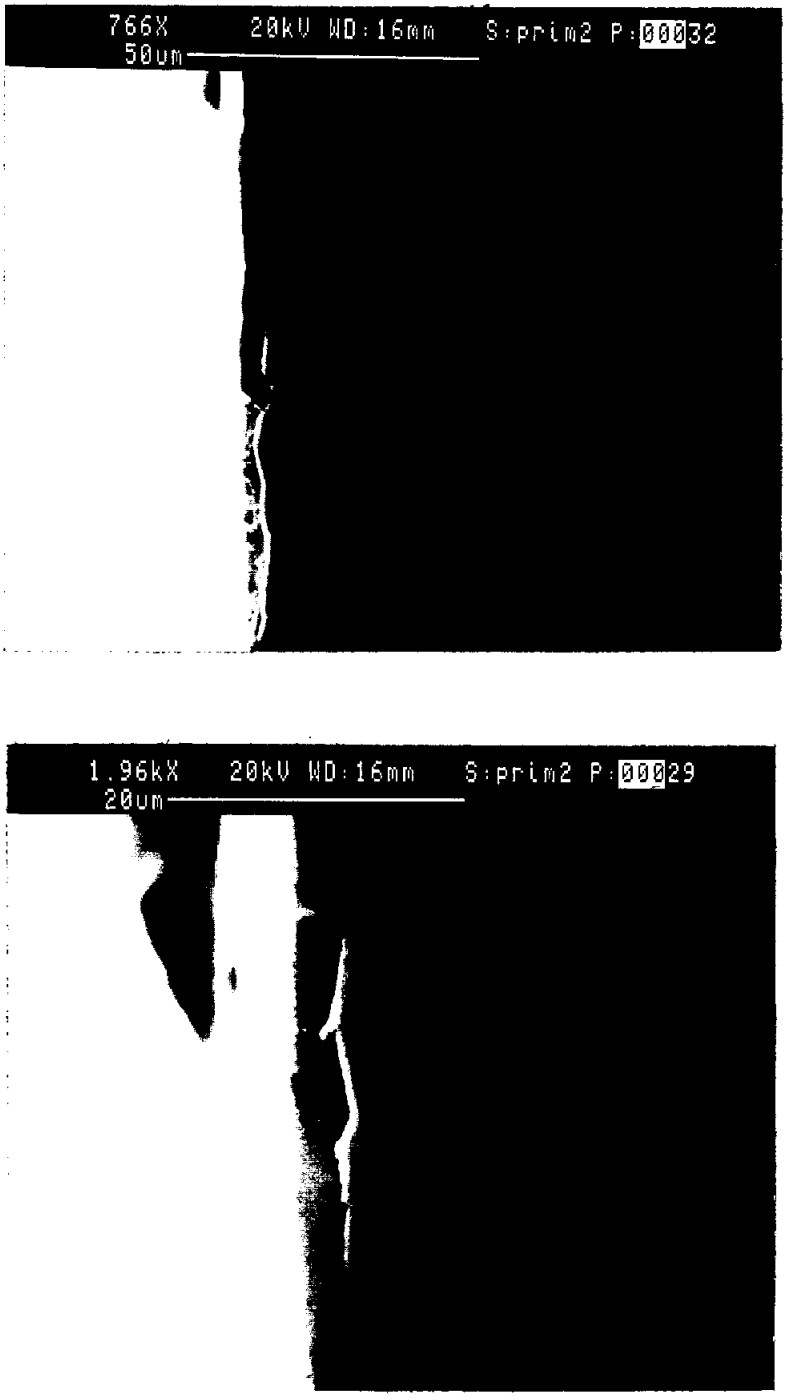


Figure 2. Typical examples of material smearing found on S/N 2956 primary lands.

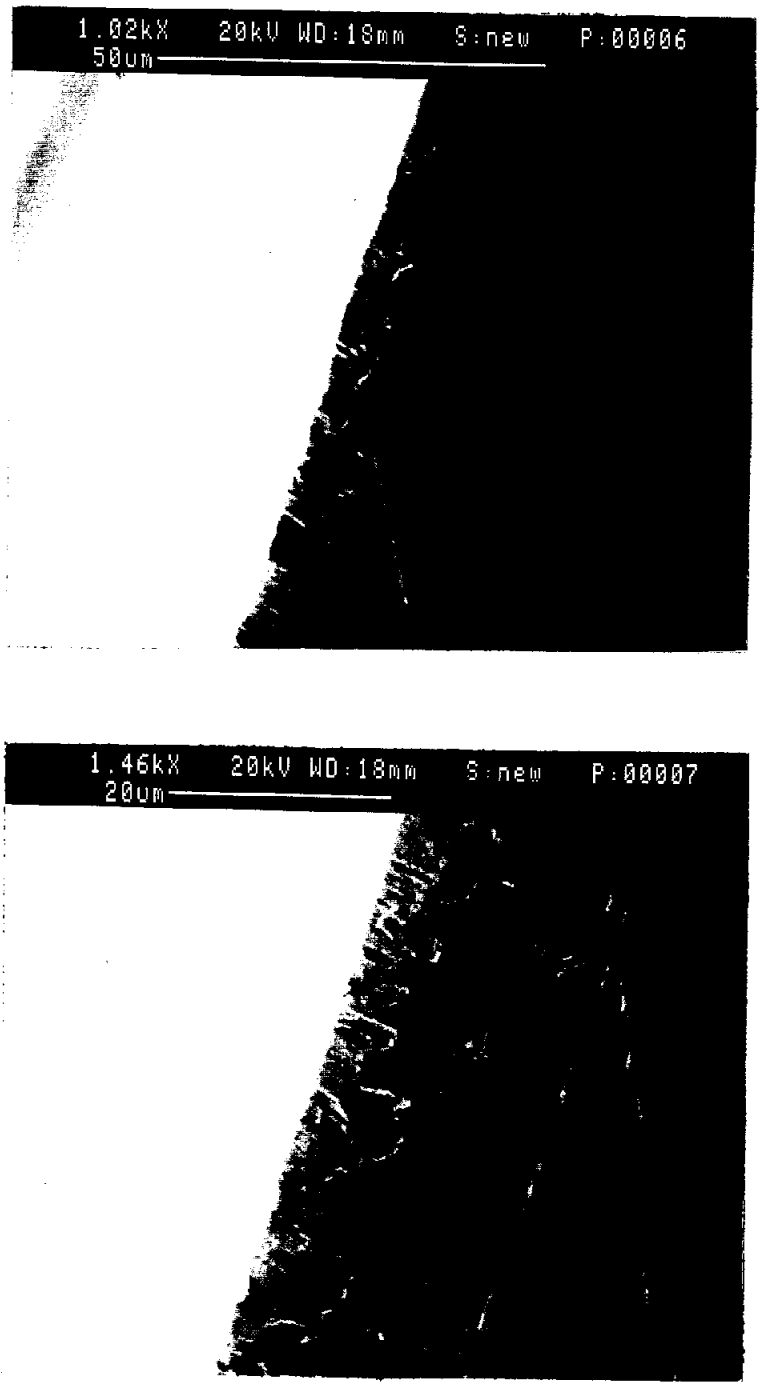


Figure 3. Examples of material smearing found on S/N 4375 primary (spool indicted as new).

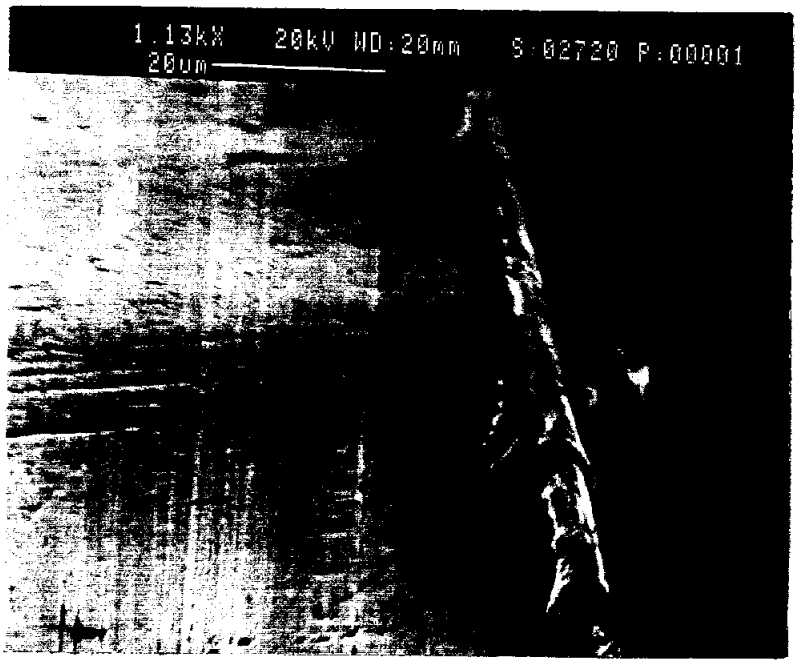


Figure 4. Example of material fold over onto land for S/N 2720 primary (trimmed but no wipe).

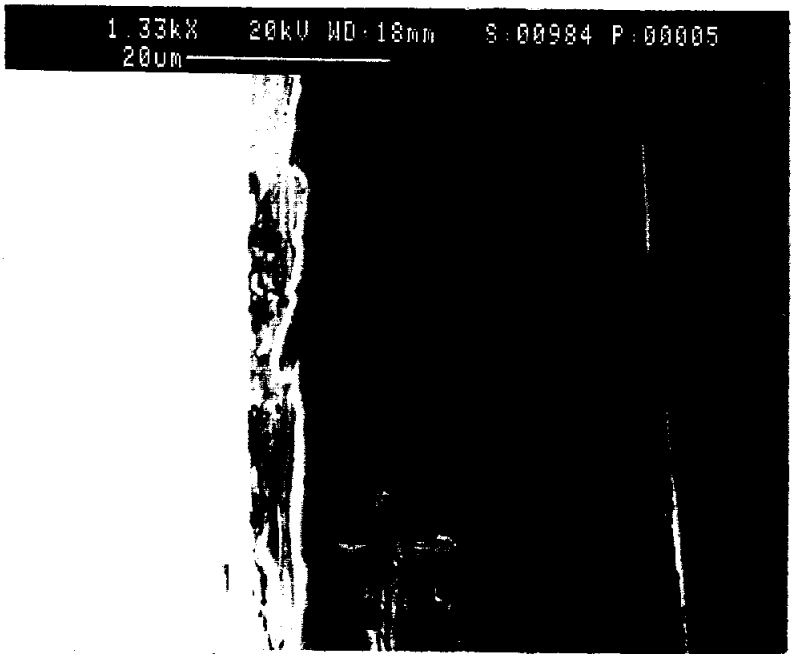


Figure 5. Example of material smear on land of S/N 984 primary (trimmed and wiped).