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

July 17, 2000

MATERIALS LABORATORY FACTUAL REPORT Report No. 00-084

## A. ACCIDENT

| | | |
|---|---|---|
| Place | : | Nantucket Island, Massachusetts |
| Date | : | October 31, 1999 |
| Vehicle | : | Boeing 767-366-ER, SUGAP |
| NTSB No. | : | DCA00-M-A006 |
| Investigator | : | Gregory Phillips |

## B. COMPONENTS EXAMINED

Lower portion of the horizontal stabilizer jackscrew.

## C. DETAILS OF THE EXAMINATION

The lower portion of the horizontal stabilizer jackscrew received for examination is illustrated in figure 1. The portion was approximately 21.5 inches long and had been separated at the location indicated by bracket "a". The screw portion illustrated is a ball screw and not a conventionally threaded screw. The helix of the ball screw is a circular groove (insert in figure 1) that matches with balls constrained within the interacting nut. The balls in the nut (not submitted for examination) are located in a helical pattern that matches the helix of the screw.

Figure 2 illustrates the fracture face indicated by bracket "a" in figure 1. The left view is the "as received" condition and the right view is after the fracture face had been saw cut from the remainder of the jackscrew and cleaned. Most of the fracture was on a slant plane, typical of overstress. However, the area indicated by bracket "b" in figure 2 contained a flat fracture region and was examined in more detail. Brackets "c", "d", "e", "f", "g" and "h" in figure 2 indicate areas on the outside diameter that are illustrated in figures 10 and 11. The red dashed lines identified as "p1", "p2" and "p3" represent cuts made to produce examination specimens "S1" and "S2".

The area indicated by bracket "b" in figure 2 is illustrated in figure 3. Specimens "S1" and "S2" and cutting lines "p1" and "p2" are indicated as in figure 2.

The fracture face was placed in a scanning electron microscope (SEM) for examination. Figure 4 is a view adjacent to the indicated cutting line "p1". Features observed at the locations indicated by circle "j", "k", "m" and "n" are illustrated in figures 5 and 6. A circumferential crack, adjacent to the separation, is indicated by arrow "q".

Ductile dimples, indicative of overstress separation, were found throughout the thickness of the fracture (from the inside diameter surface to the outside diameter surface) in the area shown in figure 4. Figure 5 illustrates the dimples observed within circle "j" of figure 4, and figure 6 illustrates the dimples observed within circle "n". The features within circle "k" and "m" were almost identical.

Specimen "S1" was saw cut from the remainder of the fracture piece, mounted, and polished for metallurgical examination. The section adjacent to the fracture face and along cutting line "p1" is illustrated in figure 7. The unmarked bracket indicates the fracture face. The circumferential crack indicated by arrow "q" in figure 4 is similarly indicated. A second significant crack located in the ball groove is indicated by arrow "r". The unmarked arrows on the composite illustration and on the middle insert indicate lesser cracks. The upper insert illustrates regularly space lapped features observed on the inside diameter of the jackscrew. The regular spacing and similarity of these features are consistent with tool marks from an inside diameter machining operation with a general finish requirement. The lower insert illustrates the initial separation edge after the surface had been etched with 2% Nital to reveal the plated surface.

Figure 8 illustrates the cracks indicated as "q" and "r" in figure 7. The etching revealed that the plating was on the surface and did not penetrate into the crack. Measurements of the plating thickness revealed that it was in the 3.6 to 4.1 micron range (0.00014 to 0.00016 inches). Energy dispersive spectrometer (EDS) analysis revealed that the plating was chromium with a trace of nickel at the interface with the base material.

The upper view in figure 9 illustrates the flat surface between the two ball grooves indicated by bracket "t" in figure 7. The plating thickness was measured at this location and found to be in the 9.1 to 9.9 micron range (0.00036 to 0.00039 inches). The lower view in figure 9 illustrates the surface in the ball groove adjacent to the one illustrated in figure 7. The corresponding location in the groove adjacent to the fracture is indicated by bracket "s" in figure 7. The plating thickness at the location shown in the lower view in figure 9 was measured and found to be in the same 3.6 to 4.1 micron range as the ball groove illustrated in figures 7 and 8.

Cracks were found on the outside surface of the jackscrew at the locations indicated by brackets "c", "d" and "e" in figure 2. Figure 10 illustrates these cracks. The unmarked arrows at location "c" indicate where three longitudinal cracks crossed the flat of the screw. The center crack progressed into the ball groove. The unmarked arrow at location "d" indicates a longitudinal crack, much shorter than those observed at location "c", that

initiated at the fracture face. The unmarked arrow at location "e" indicates a circumferential crack similar to the one indicated by arrow "q" in figure 4.

Cracks were also found on the outside surface of the jackscrew at the locations indicated by brackets "f", "g" and "h" in figure 2. Figure 11 illustrates these cracks. The unmarked arrows at location "f" indicate six small longitudinal cracks, within the ball groove, that initiated at the fracture face. The two unmarked arrows at location "g" indicate the cracks initiating at the fracture face. The left arrow indicates a crack that initiated at the fracture face, propagated across the groove, along the flat of the screw and into the adjacent groove.

Multiple cracks were found at the "h" location, as shown in the lowest photograph in figure 11. The two unmarked arrows at location "h" indicate small cracks initiating from the fracture face. The cracks arrowed "v" and "w" start at the fracture face and propagate across the ball groove. Arrow "p3" in the lowest photograph in figure 11 indicates the red dashed cutting line as indicated in figure 2. Also, arrow "u" indicates a red dashed cutting line that crossed cracks "w" and "v" and divided specimen "S2" into two pieces. The lower piece (further from the fracture) was metallurgically prepared for examination. The upper piece was then separated in the directions indicated by arrows "v1" and "v2" (see figure 11) in order to examine the face of crack "v".

A view of the polished surface along cutting line "u" (see figure 11) is illustrated in figure 12. The cracks indicated by arrows "v" and "w" are similarly identified. The unmarked arrows indicate very shallow surface cracks. Hardness testing was performed on this prepared specimen utilizing an Antonik micro hardness tester, model MHT2 (Knoop indenter at 500g). The results indicated that the hardness was within a range of 55 – 60 HRC (Hardness, Rockwell, C scale) from the chrome plating to a depth of approximately 0.04 inches. From the depth of 0.04 inches to 0.10 inches the hardness was in the range of 45 – 52 HRC and from a depth of 0.10 inches to 0.35 inches the hardness was in the range of 42 – 45 HRC. Direct hardness measurement utilizing an Antonik hardness tester, model ADR8 ("C" indenter at 150Kg), indicated that the hardness was 43.2 HRC at a depth of 0.09 inches, 40 HRC at a depth of 0.18 inches and 40.8 HRC at a depth of 0.27 inches.

Figure 13 illustrates higher magnification views of the intersection of cracks "v" and "w" with the exterior surface of the jackscrew. The unmarked arrows indicate the cleanly separated chromium plating. Several of the smaller surface cracks on both sides of cracks "v" and "w" (indicated by the unmarked arrows in figure 12) are visible in figure 13. Chromium plating thickness on the section shown in figure 13 was in the same range as the upper view of figure 9.

The face of crack "v" separated at arrows "v1" and "v2" in figure 11, location "h", is illustrated in figure 14. The crack face shown in this figure was the face on the portion of the jackscrew under the arrow "v2" in the lowest photograph in figure 11. The unmarked arrow in figure 14 indicates the material that was mechanically removed to assist in opening crack "v" and the material in the bracket is the fracture area created in the

laboratory. The surface of crack "v" (indicated by arrow "v2" in figure 14) contained relatively uniform dark rust-colored deposits. Examination of the crack face revealed features that were consistent with an overstress separation.

[redacted]

Derek Nash
Mechanical Engineer

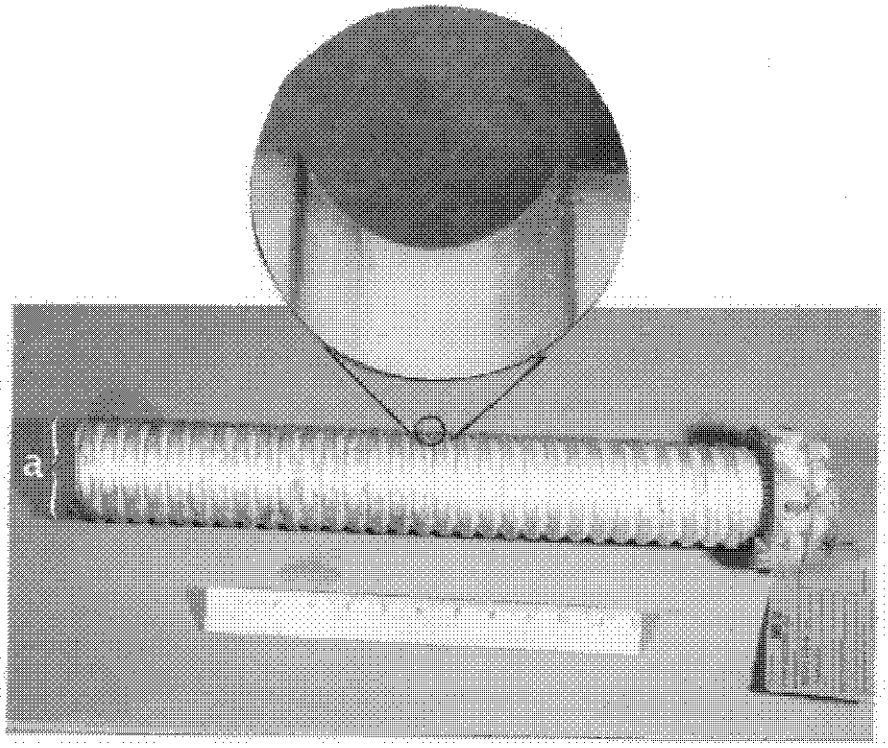


Figure 1. The lower portion of the jackscrew received for examination.

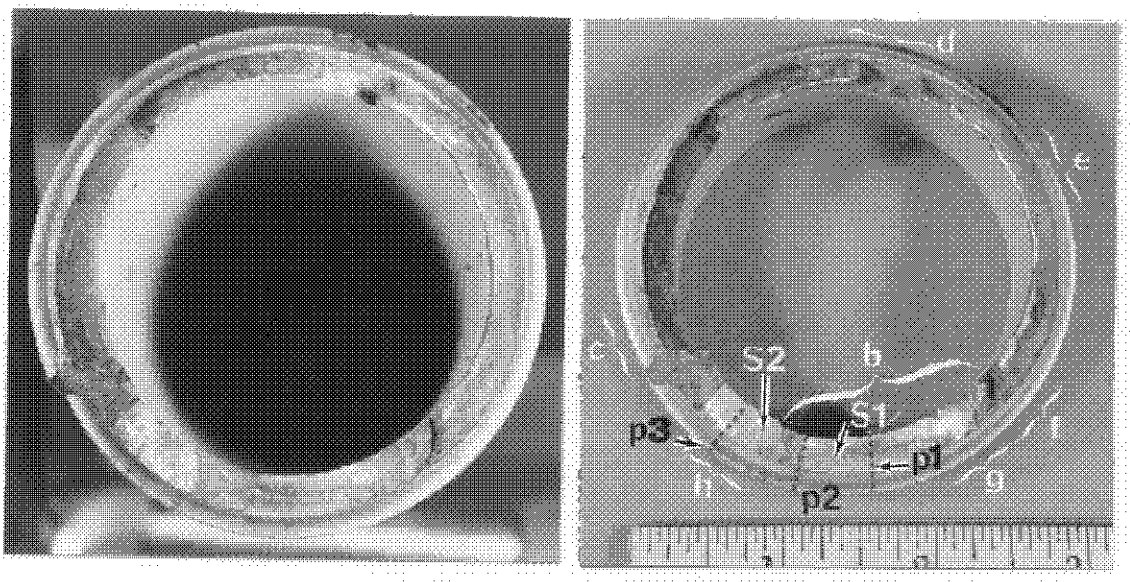


Figure 2. The jackscrew fracture face as received (left view) and after cleaning (right view).

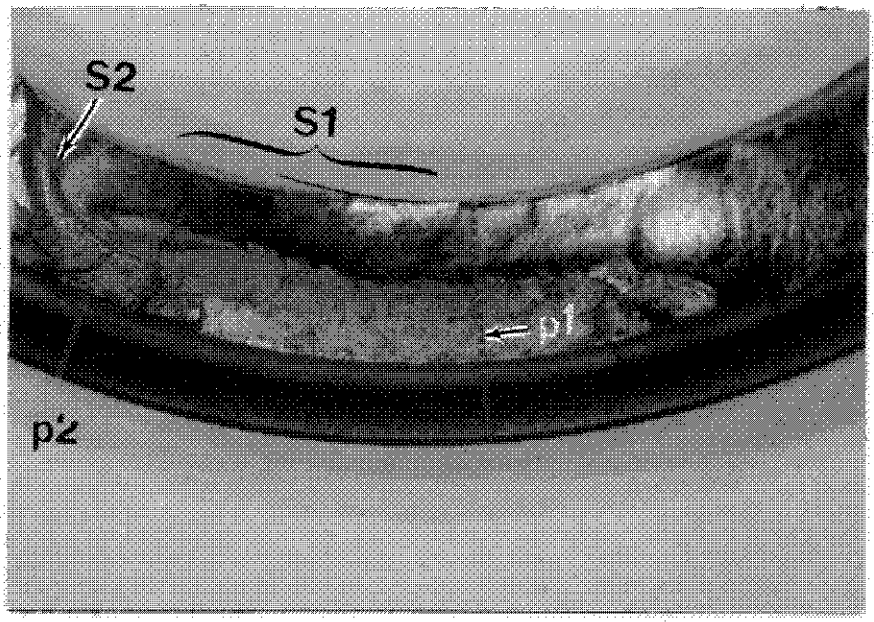


Figure 3. The area indicated by bracket "b" in figure 2. (3.7X)

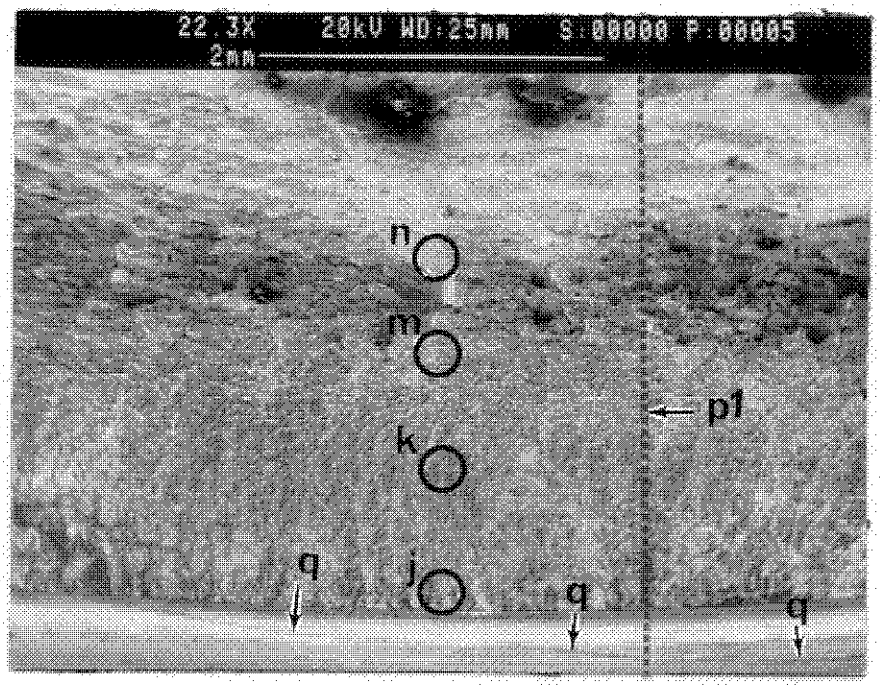


Figure 4. SEM photograph of the area of the fracture face adjacent to the cutting line "p1". (22.3X)

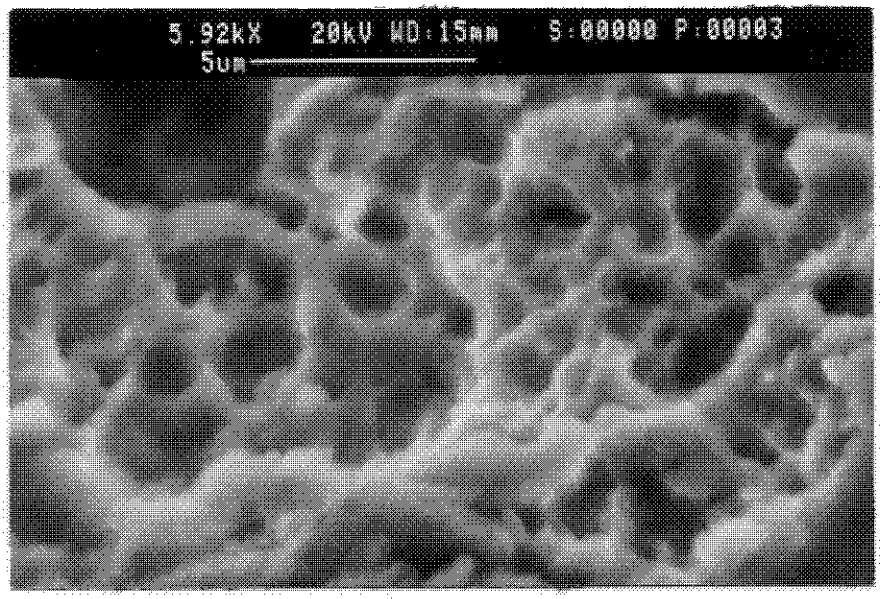


Figure 5. SEM photograph of the surface features observed within circle "j" of figure 4. (5,920X)

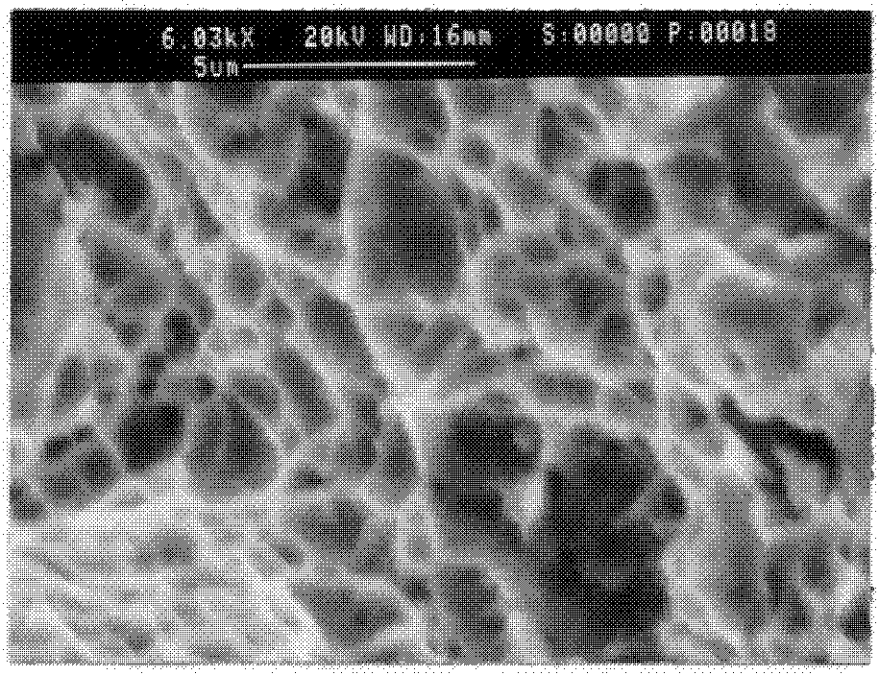


Figure 6. The surface features observed within circle "n" of figure 4. (6,030X)

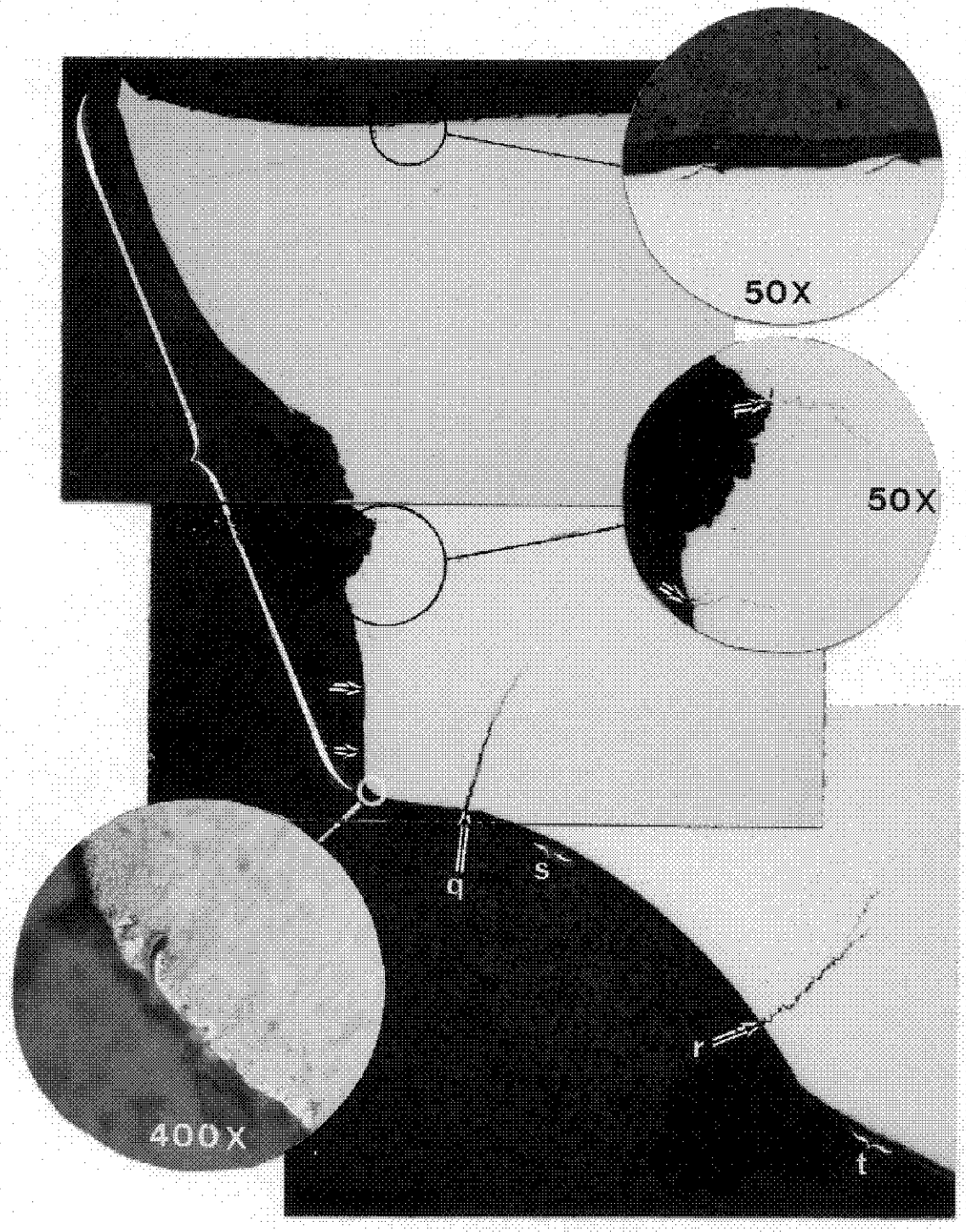


Figure 7. Sectional view of the fracture face and the adjacent ball groove along cutting line “p1”. (20X)

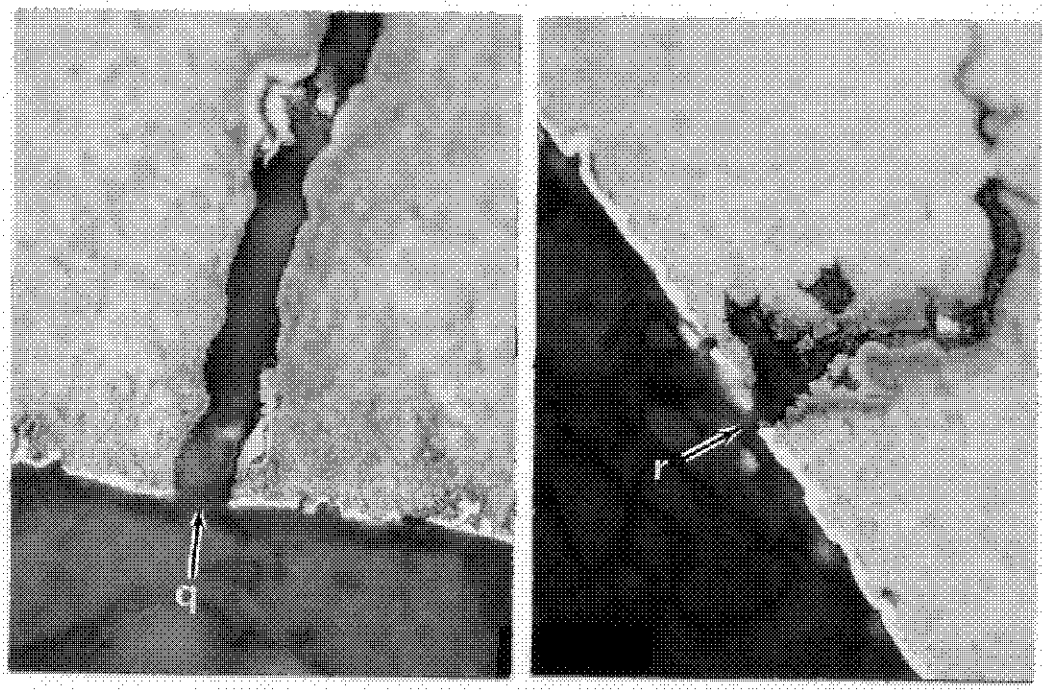


Figure 8. Closer view of the intersection of cracks "q" (left view) and "r" (right view) with the surface of the jackscrew. (Nital etchant, 400X)

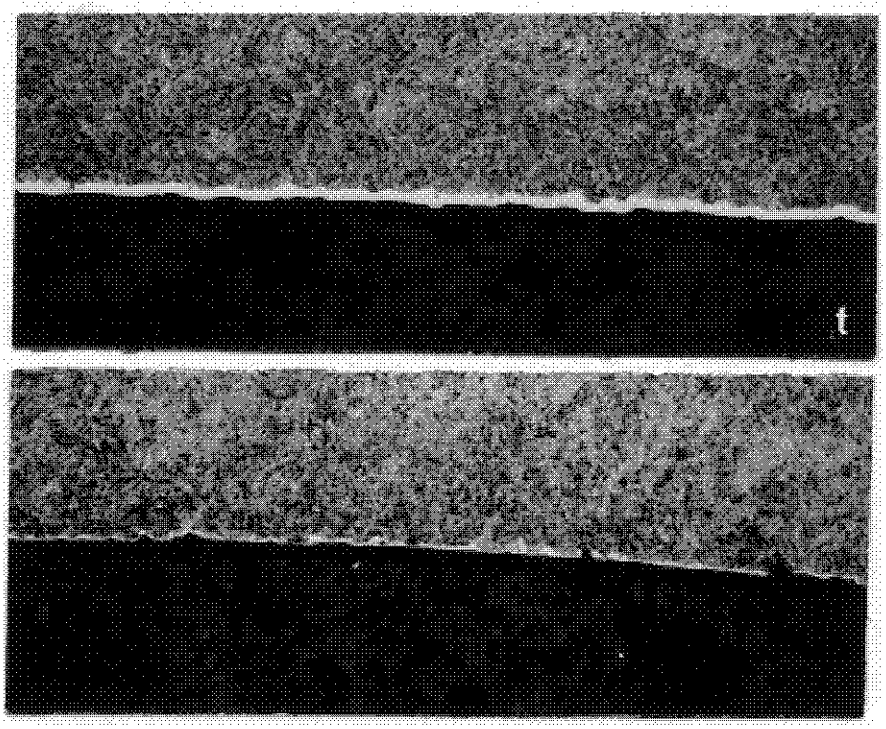


Figure 9. Views showing the plating thickness at bracket "t" (top view) in figure 7 and in the ball groove (lower view) adjacent to the one illustrated in figure 7. (Nital etchant, 200X)

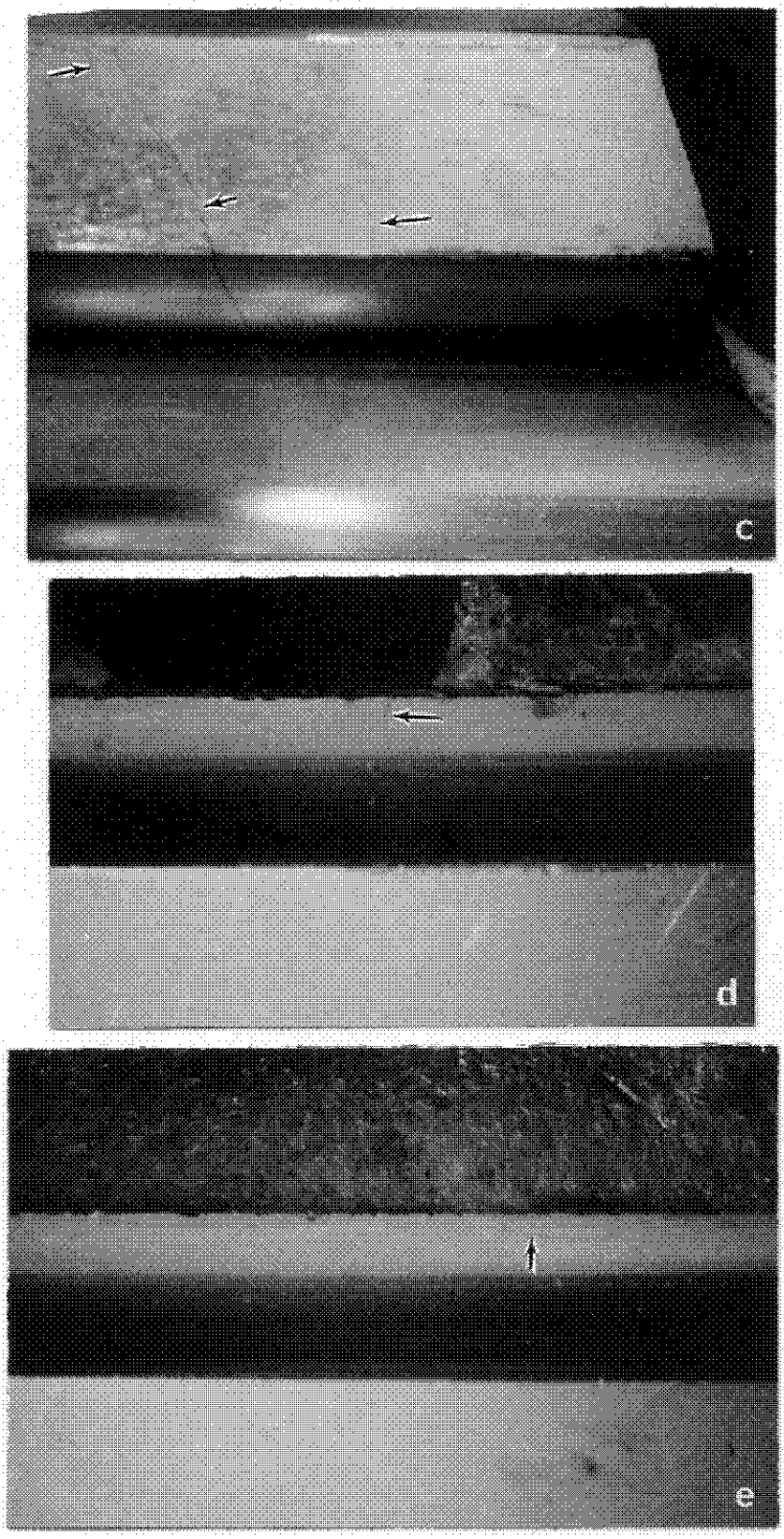


Figure 10. Cracks observed at locations “c”, “d” and “e” in figure 2. (10X)

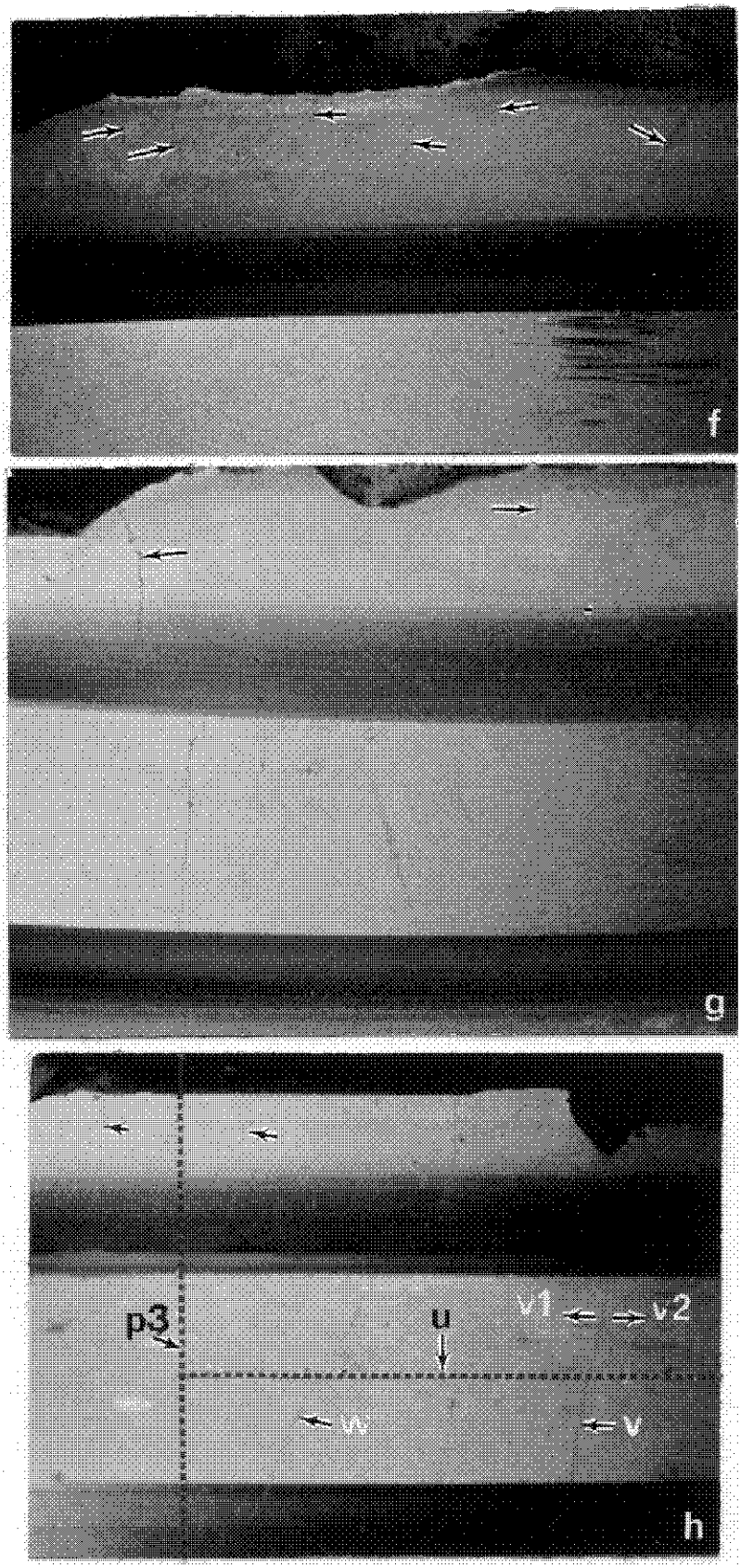


Figure 11. Cracks observed at locations “f”, “g” and “h” in figure 2. (10X)

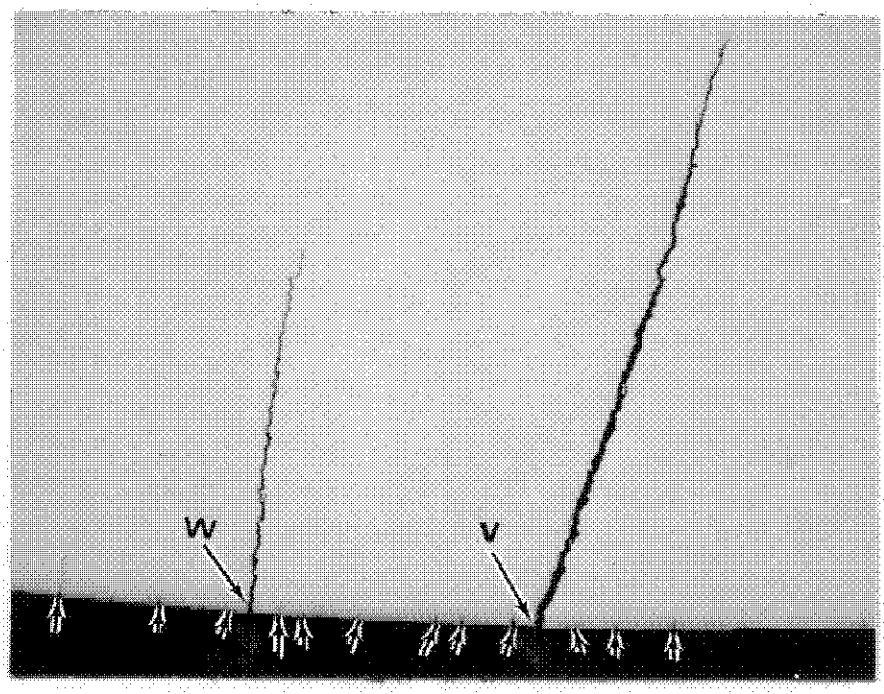


Figure 12. Sectional view on cutting line "u" in figure 11 location "h" with cracks "v" and "w" indicated. (As-polished, 20X)

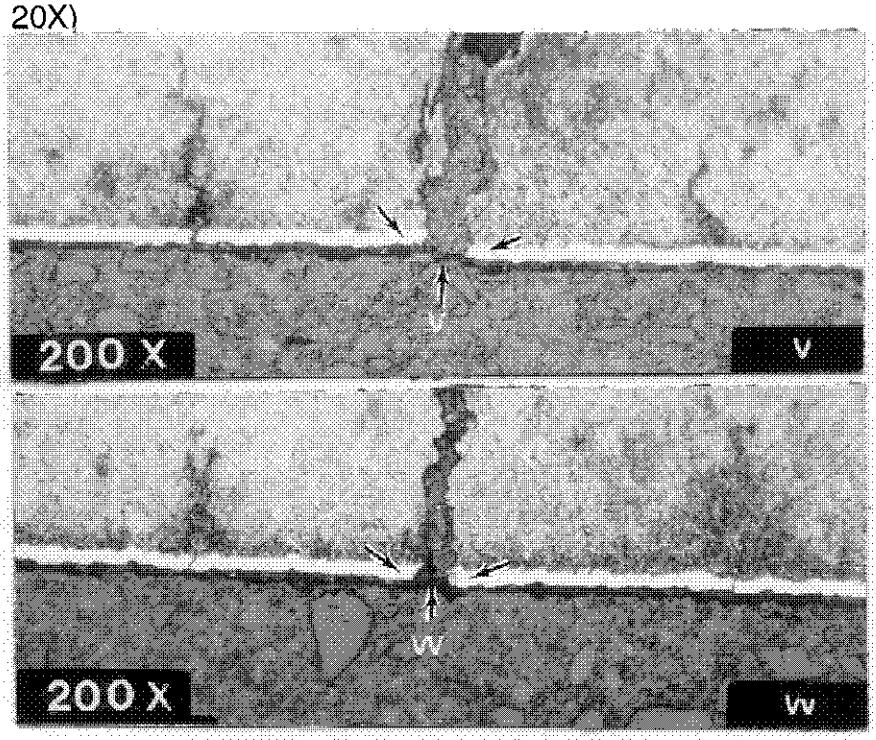


Figure 13. Closer views of the intersection of cracks "v" and "w" with the exterior surface of the jackscrew. (Nital etchant, 200X)

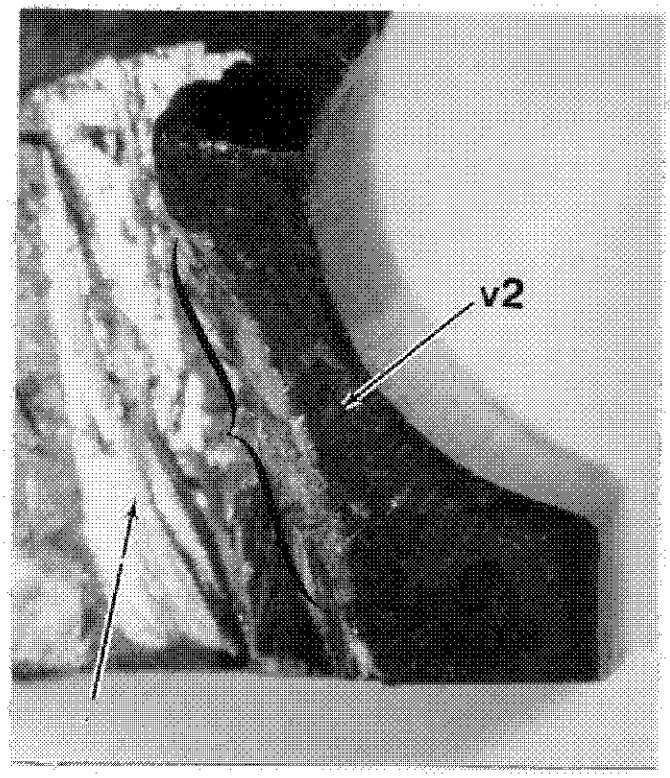


Figure 14. Fracture face "v2" of crack "v" in figure 11, location "h". (6.5X)