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EXTRUSION DEFECTS ON 90/10 AND 70/30 COPPER-NICKEL TUBES

by

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PHYSICAL METALLURGY DIVISION

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EXTRUSION DEFECTS ON 90/10 AND 70/30 COPPER-NICKEL TUBES

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SUMMARY OF RESULTS

Surface cracks observed on the leading ends of 90/10 and 70/30 cupro-nickel extrusions have been vacuum impregnated and their extension beneath the surface studied. From polished sections and a brief survey over the extrusion process, the formation of these cracks has been discussed and explained, and suggestions for an improvement have been made.

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INTRODUCTION

On tubes of various diameters extruded from 70/30 and 90/10 cupro-nickel alloys, longitudinal cracks on the surface have been observed, which appeared preferentially on the leading ends of the extrusion.

During a visit to Noranda Copper Mills Limited, Montreal, P.Q. on July 2, 1964, these defects and their origin were discussed with Mr. P.A. Scully, Metallurgical Manager and his staff.

In the meeting with Mr. Scully, the following possible sources for these cracks were discussed:

1. Impurities
2. Segregation
3. Cracks introduced by machining the billet surface before extrusion
4. Imbalanced heat distribution prior to extrusion
5. Imbalance in extrusion equilibrium.

HISTORY OF THE BILLETS

From the melt, the round billets were cast 8 in. (203 mm) in diameter. They then were machined to 7-5/8 in. (194 mm) diameter. After machining, the billets were preheated: the 70/30 alloy to 980°C and the 90/10 alloy to 830°C. The billets were extruded at an extrusion ratio of absolutely 21 or logarithmically of $\ln \frac{1}{21} = 4.18 = 480\%$.

On the leading end of the extrusion these tubes showed longitudinal cracks as reported above, so that approximately 20 to 30% of the tubes had to be scrapped.

PROCEDURE

Samples of cracked specimens have been vacuum impregnated with a resin of low viscosity which penetrated the cracks. The specimens then were cut and polished in two perpendicular directions as shown in Figure 1. A and B represent the two perpendicular areas which have been polished.

Figure 2A and Figure 3A show the failures observed on plane A. The grey phase is the resin, the white one the metal. It can be seen that the surface appears very irregular and that from the valleys on this surface, cracks run off to a depth of approximately 0.022 in. (0.5 mm). Figures 2B and 3B show the extension of these cracks in the longitudinal direction after the sample has been polished on side B. (See Figure 1). It can be seen clearly that these cracks show the tendency to form attached flakes of varying thicknesses. For both alloys, the same results were obtained as can be seen in Figures 4A and 5A, and 4B and 5B.

The fact that these cracks appear only

a) in the leading end of the extrusion, or

b) show a clean separation of material under the surface at a certain depth, eliminates the possibility that impurities and/or segregation might alone be responsible for them.

That the cracks have been introduced by machining does not explain the fact that these marks only show on the leading ends of the extrusion.

If it is realized that every extrusion process is more or less limited by the amount of friction, it will be easily understood that the changes in friction during the extrusion process will influence the material flow on the surface considerably. At the beginning, static friction is the ruling element and this gradually changes to dynamic friction, and back to static again as the butt is reached. Until the flowing material can transport sufficient lubricant to the die surfaces, and this will be at the beginning of the extrusion, the unlubricated or barely lubricated die surfaces will introduce shearing forces which make the material flow in other than the intended directions. This leads to a partial separation of the material as is well demonstrated in Figures 5 to 7.

Another important factor is the difference in material strength resulting from temperature differences within the billet. The front and the end section of the billet come into close contact with the die face, container wall, and extrusion stem, respectively, where the heat dissipates faster out of the billet than in its centre. This results in a rather complicated internal stress distribution, and when - to this effect is added the external extrusion force - the hotter centre of the billet tends to flow faster than the front and front end walls.

These two factors,

(a) the lubricant deficiency at the beginning, and
(b) the temperature imbalance over the billet length,

will locally raise internal stress so high that the material cannot compensate it by flowing and adapting to the shape forced upon it. Instead, it fails to cohere and it cracks. In order to have an idea of the necessary loads to cause material failure, the tensile strength of these materials at elevated temperatures should be taken into consideration. 70/30 cupro-nickel has a tensile strength of 40,000 psi at 425°C. At 640°C it is only 10,000 psi. The figures will be of the same order of magnitude for a 90/10 Cu-Ni alloy.

It is likely that impurities act as stress raisers but not necessarily so. As soon as the lubricant has formed the desired lubrication film and the material's temperature distribution becomes homogeneous, the extrusion will proceed without any failures until it reaches the extrusion end, the butt.

CONCLUSIONS

The following should be tried to reduce the length of cracked tubes:

1. The billet should be superheated on the leading end by an amount sufficient to accommodate the heat losses.

2. The extrusion speed should be low at the beginning and be increased during the extrusion.

3. Care should be taken that the die surface is lubricated properly right from the beginning.

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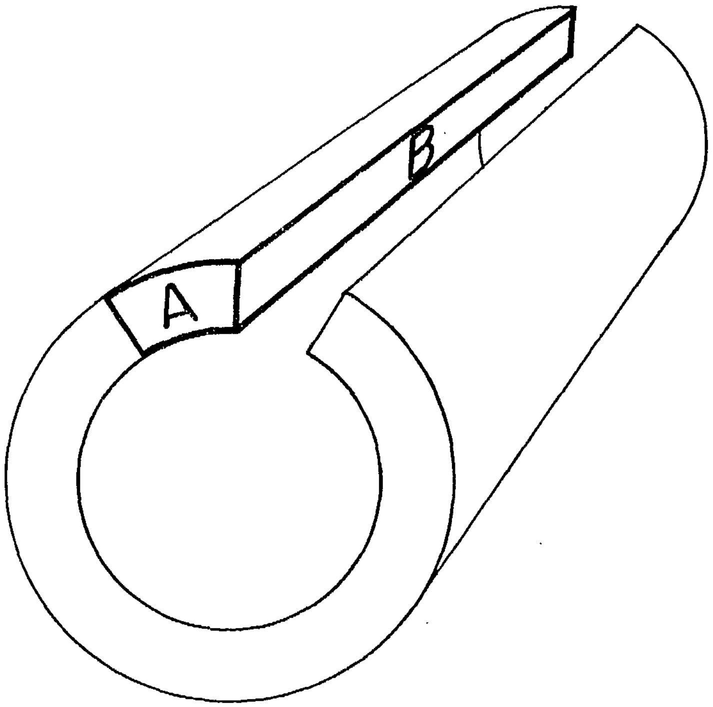


Figure 1. Cross-sectional view of tube indicating where samples have been taken. A and B represent the polished sections.

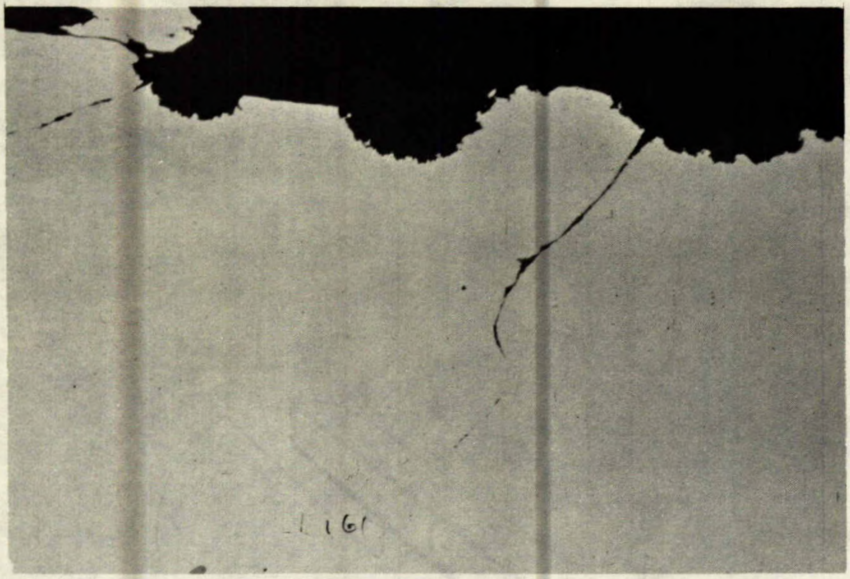


Figure 2A.

X150

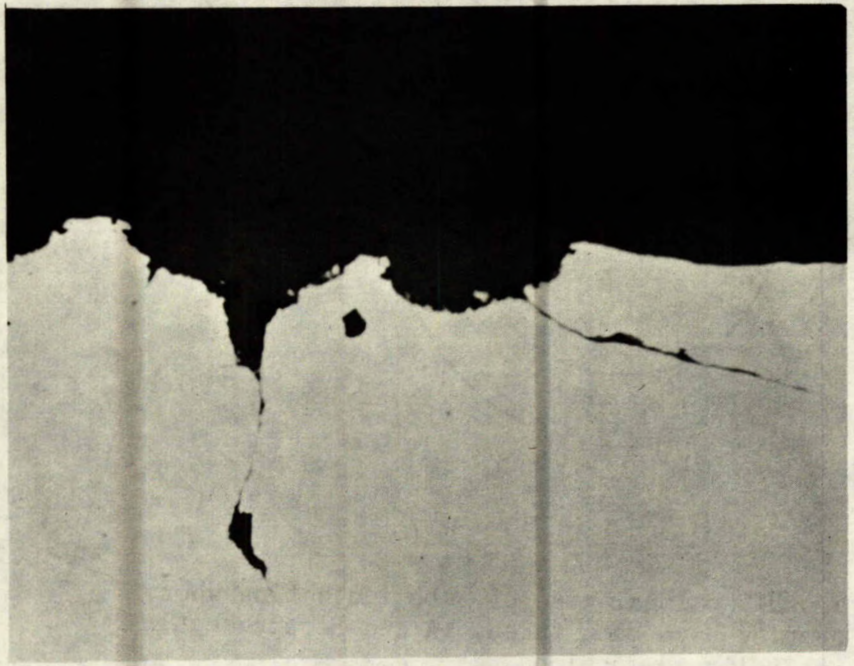
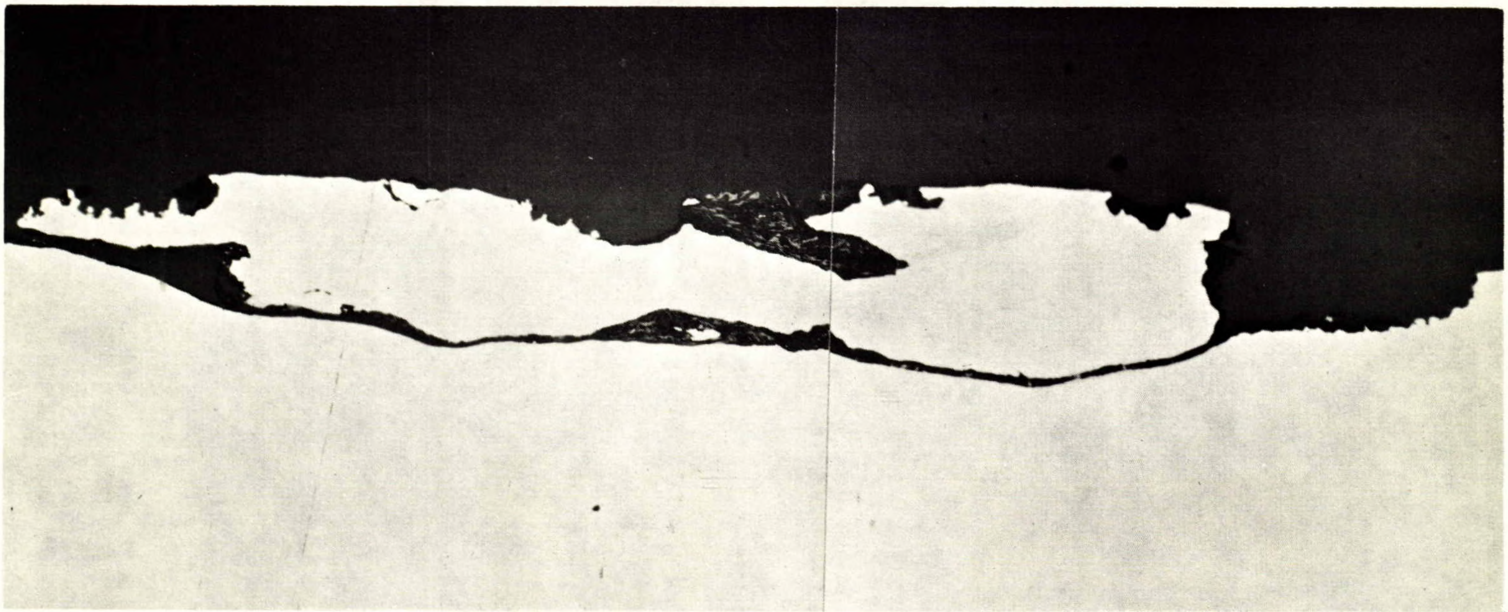


Figure 3A.

X150

Cross-sectional view of a polished 90 Cu-10 Ni alloy tube surface impregnated with resin.

Figure 2B



X150

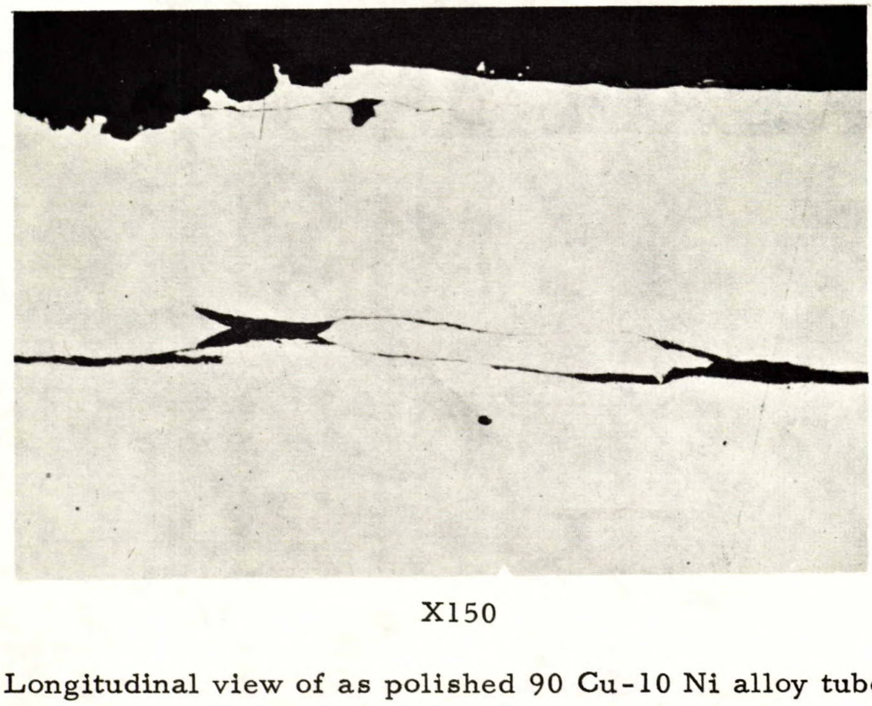


Figure 3B

X150

Longitudinal view of as polished 90 Cu-10 Ni alloy tube surface impregnated with resin.

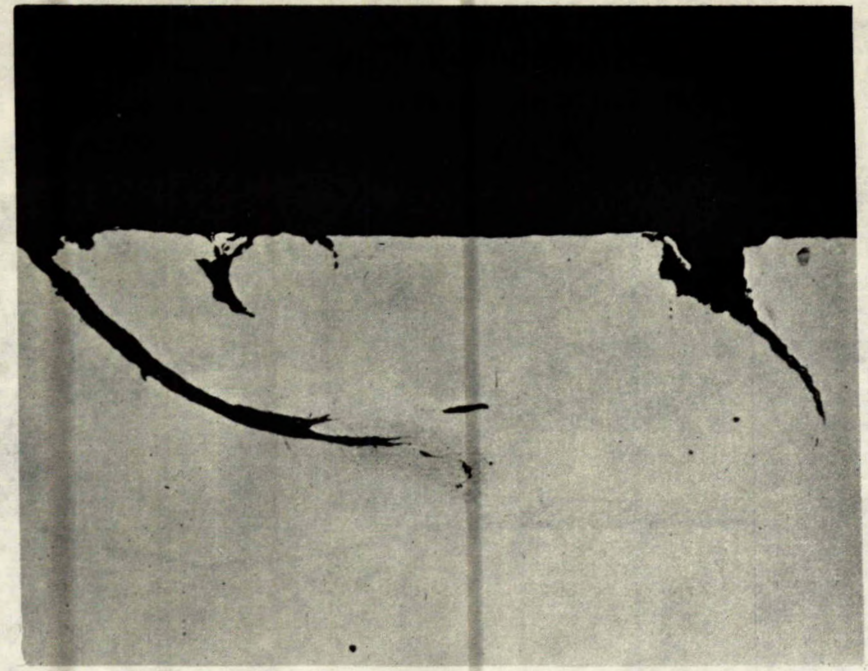


Figure 4A.

X150

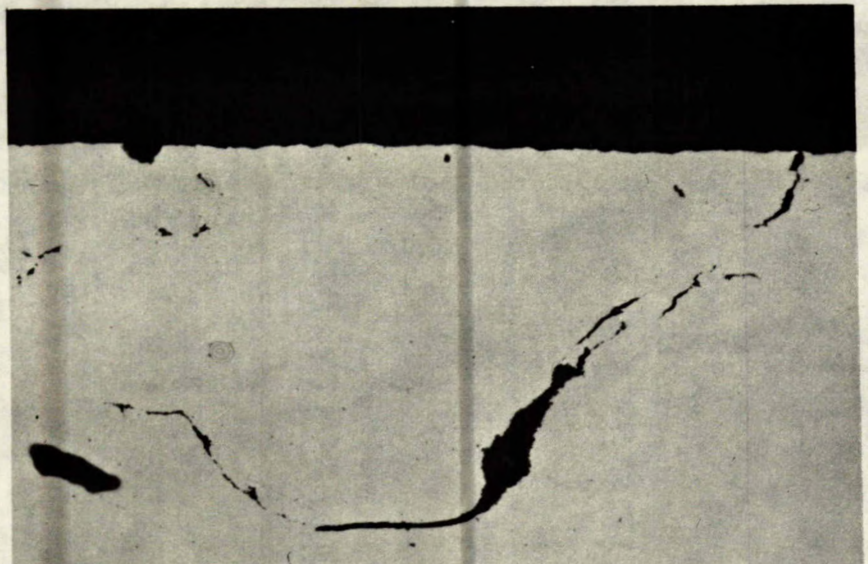


Figure 5A.

X150

Cross-sectional view of a polished 70 Cu-30 Ni alloy tube surface impregnated with resin.

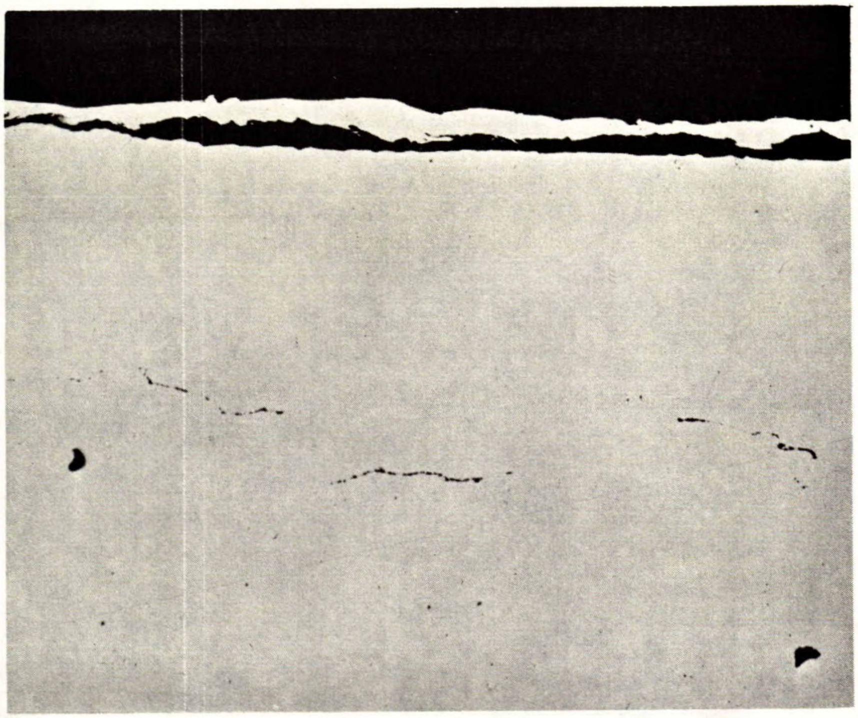


Figure 4B

X100

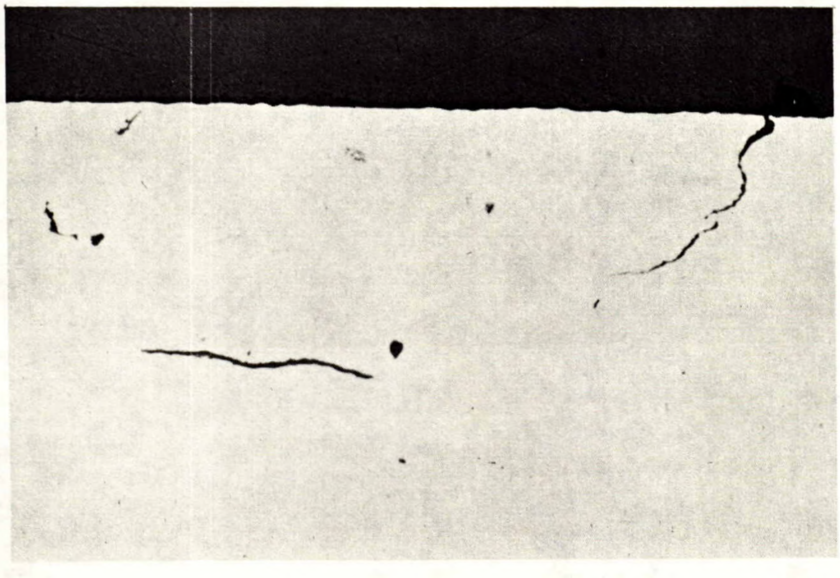
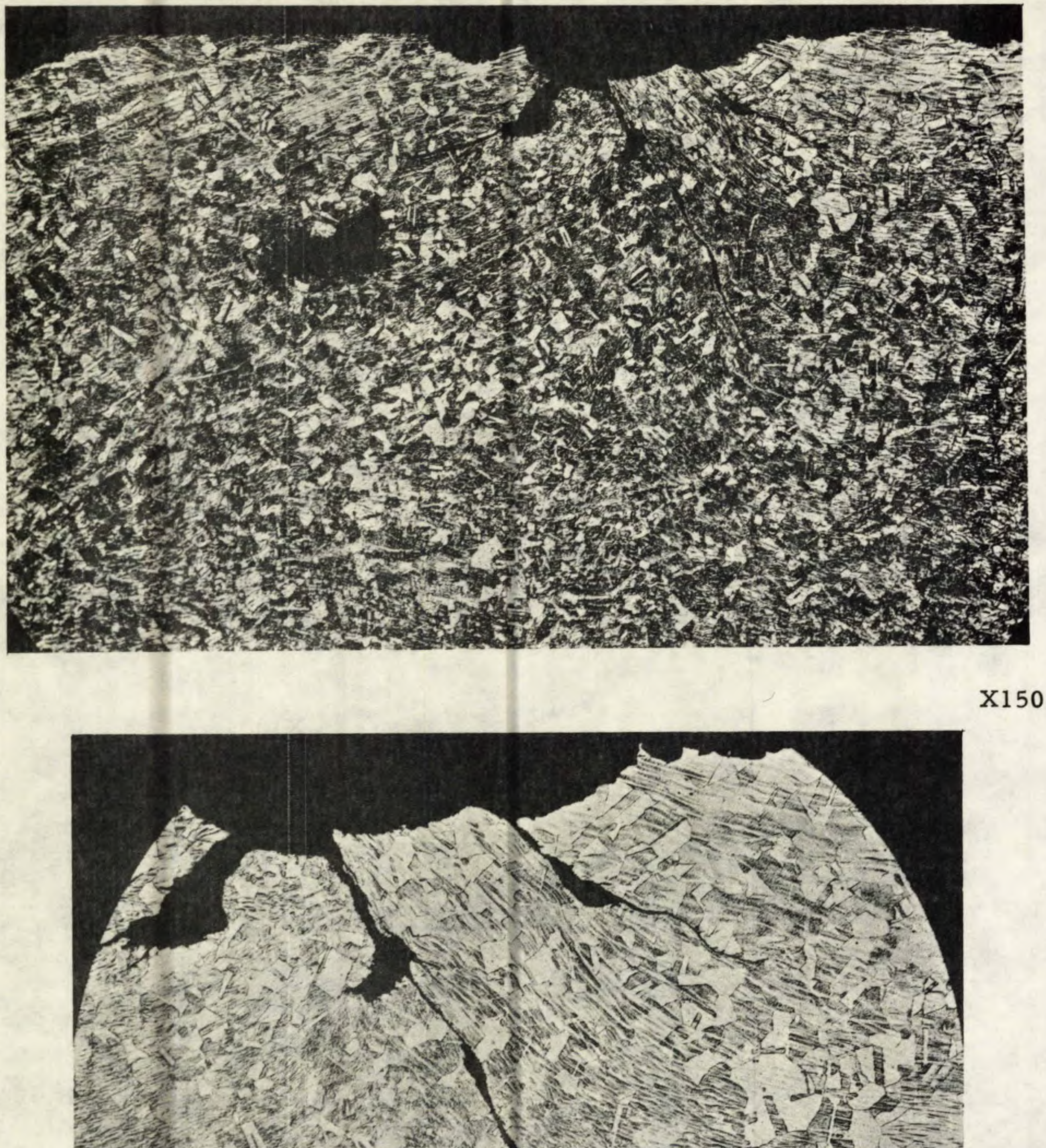


Figure 5B.

X100

Longitudinal view of a polished 70 Cu-30 Ni alloy tube surface impregnated with resin.



X150

Figure 7. 90 Cu-10 Ni Alloy. X300

Note the lamellar appearance which suggests some local shear as opposed to the main extrusion direction.