CoA Memo. No. 113

September, 1966

THE COLLEGE OF AERONAUTICS

DEPARTMENT OF MATERIALS

Investigation into the effect of material properties and processing upon the springback characteristics of a 1.0% chromium 0.3% molybdenum steel

- by -

Roger Pearce

Introduction

The principal properties which affect springback are known; these are modulus, yield-strength and rate of work hardening. A sheet of 1.0% Cr/0, 3% Mo in an steel (0.064" × 36" × 126") has been tested in an attempt to map out the variation in these and other relevant properties and so to see whether this property variation could be the cause of the unsatisfactory roll-forming behaviour experienced, (Fig. 1). Finally, various heat-treatments have been tried, to determine their affect on relevant mechanical properties and their variation. Testing has been carried out on the Instron tensile testing machine and heat-treatment in a conventional laboratory furnace.

Modulus

It was decided not to measure elastic modulus directly in this investigation, as very precise techniques are required for the results to be meaningful. Instead, the strain ratio, r, was measured, which is an indirect check on modulus. That is to say, wide variations in r would suggest a variation in elastic modulus.[1]

Yield point

This steel showed discontinuous yielding, and so a lower yield-point could be easily determined from the autographic load-extension curve.

---

1 To calculate the strain ratio, r, the following formula was used:

$$r = \frac{\log_{10}(^{Wo}/Wx)}{\log_{10}(^{Wx}/Wo\ ^{Lx}/Lo)}$$

where Wo = initial width

Wx = width at x% total strain

Lx = length at x% total strain

Lo = initial length

r was measured at approximately 5, 15 and 20% strain, and as no significant differences were found the results quoted are the averages of all the values obtained.

Work hardening behaviour

The ratio of yield load/maximum load (YL/ML) was taken as a measurement of the slope of the load/elongation curve and consequently a measure of the work hardening behaviour of this material. For a material conforming to the empirical stress-strain relationship:

$$\sigma = K\epsilon^{n},$$

where σ = true stress

ϵ = true strain

K = constant 1

n = work hardening coefficient

$$YL/ML = \left[\frac{k}{n}\right]^{n}$$

can be derived, where k = constant 2.

Experimental procedure

A sheet was cut into four equal parts, A, B, C and D of dimensions $31\frac{1}{2}''$ × 36″, as shown in Figure 2. Each piece was then further cut up as shown in Figure 3, and then cut into 8″ strips, which were in turn milled into eight-inch gauge-length tensile specimens. These were tested at a strain rate of 0.1 inches/min.

Results

The values obtained of yield strength, strain ratio and YL/ML are shown in Figures 4, 5 and 6. Photomicrographs of relevant microstructures are shown in Figures 7 and 8.

Discussion

There is clearly a change in properties from one end of the sheet to the other. The yield strength rises steadily from 3.84 to 4.38 x 10^4 lbs/in^2, showing twice the variation shown by the tensile strength, these latter variations also being more scattered. The YL/ML ratio varies from 0.60 to 0.45 approximately, the lower value being, naturally, associated with the lower yield-strengths. The strain ratio r varies from 0.84 - 9.9 non-systematically, which suggests that the modulus is constant within this sheet for all practical purposes.

This sheet would, in all probabilities not have produced a symmetrical roll-formed product, the end showing the higher yield strengths and higher

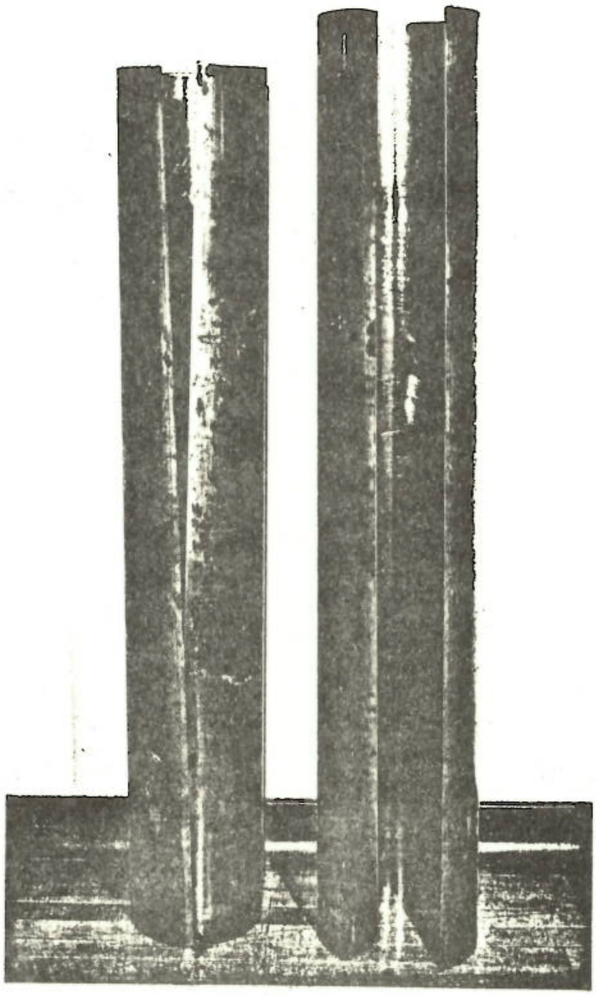
YL/ML ratios would have shown a greater gap than the other end.

A heat treatment, attempting to 'level out' these properties, was now given to tensile-test pieces cut adjacent to those already used. Following practice used elsewhere, the specimens were annealed at 950°C and then furnace-cooled overnight (about 14 hours). This gave the results shown in Figures 9, 10 and 11 and the microstructures shown in Figures 12 and 13.

It can be seen that the properties are now more uniform along the sheet length and so less roll-forming variation would be expected. It should be noted that the total elongation of the material has dropped from about 20% to about 17.5%, but this should not affect the roll-forming operation.

Conclusions

The variation in mechanical properties found along the sheet length could affect the variable roll formability found in certain batches of this steel. A heat treatment consisting of annealing at 950°C and cooling slowly, appears to give a more even (but slightly different) distribution of properties. It is recommended that a batch of sheets be heat-treated in this way on a production run. Any cold working operations imposed after final annealing should be discontinued.



(d) (b)

Figure . 1 .

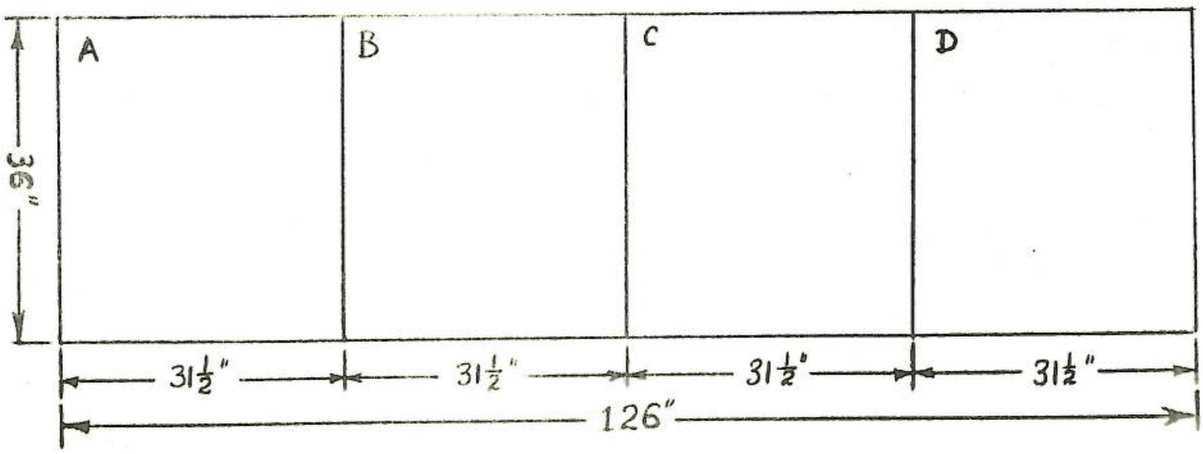


Figure . 2.

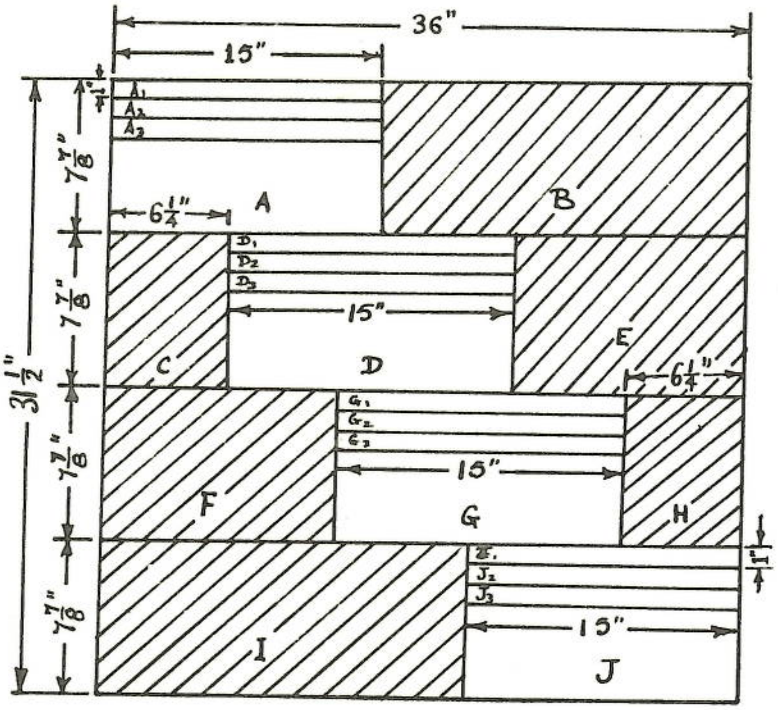


Figure. 3.

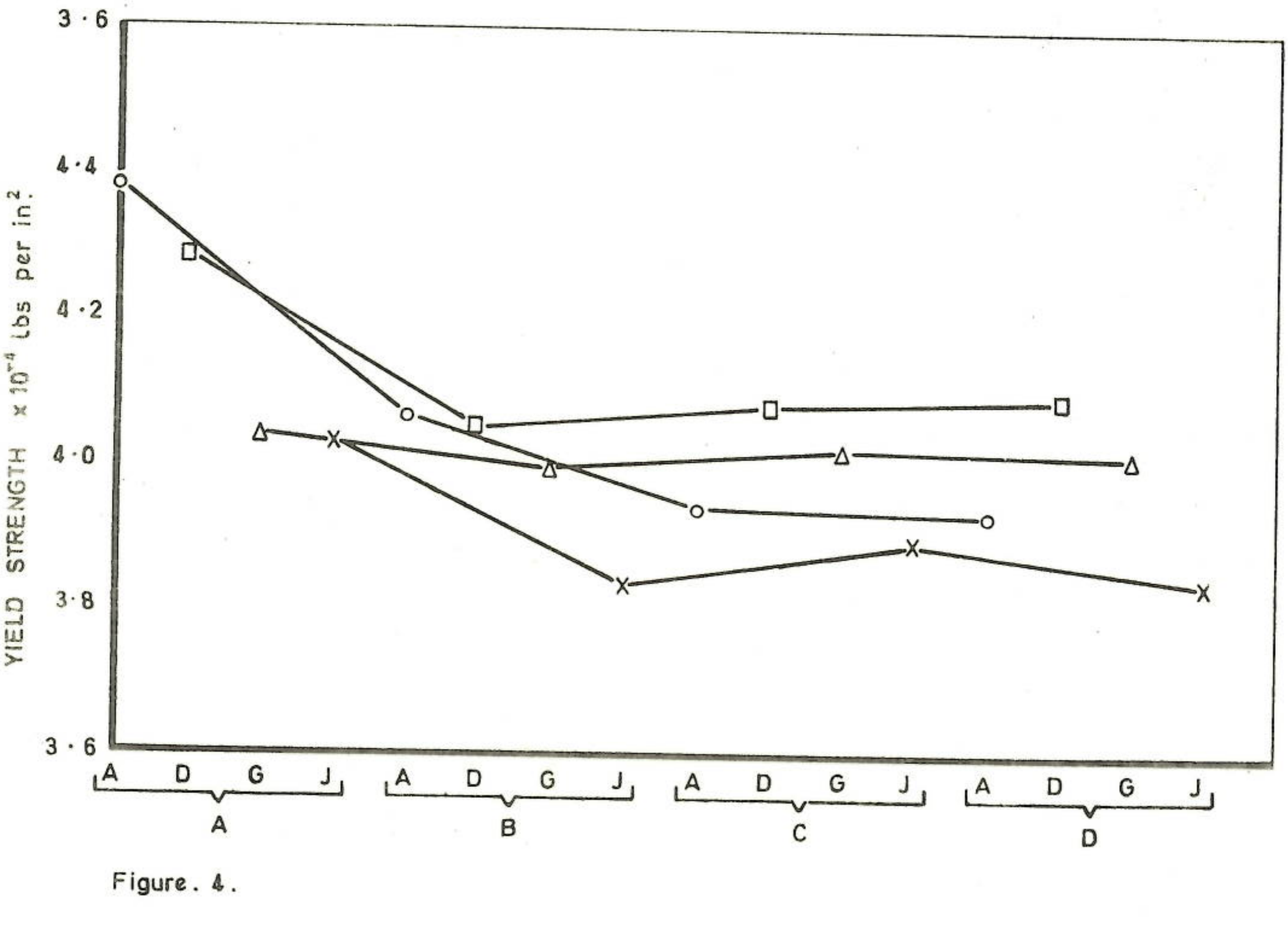


Figure. 4.

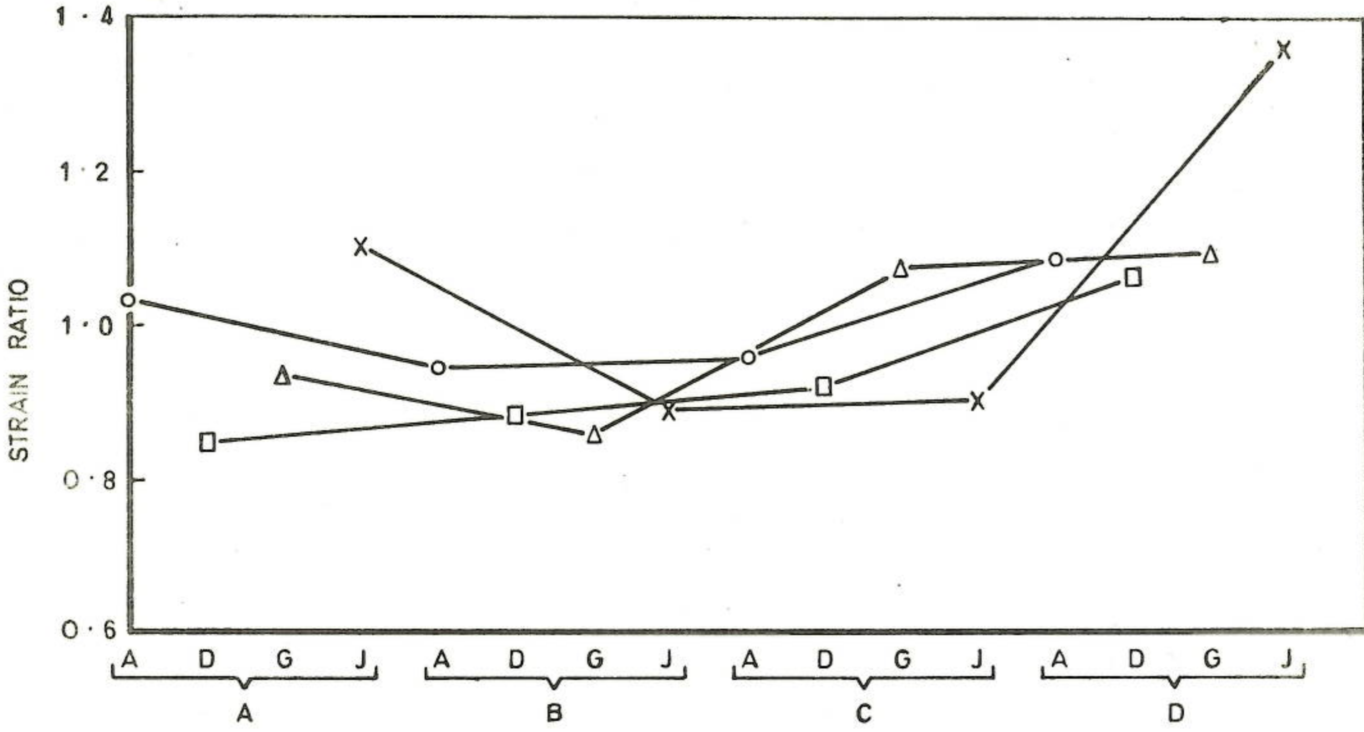


Figure 5

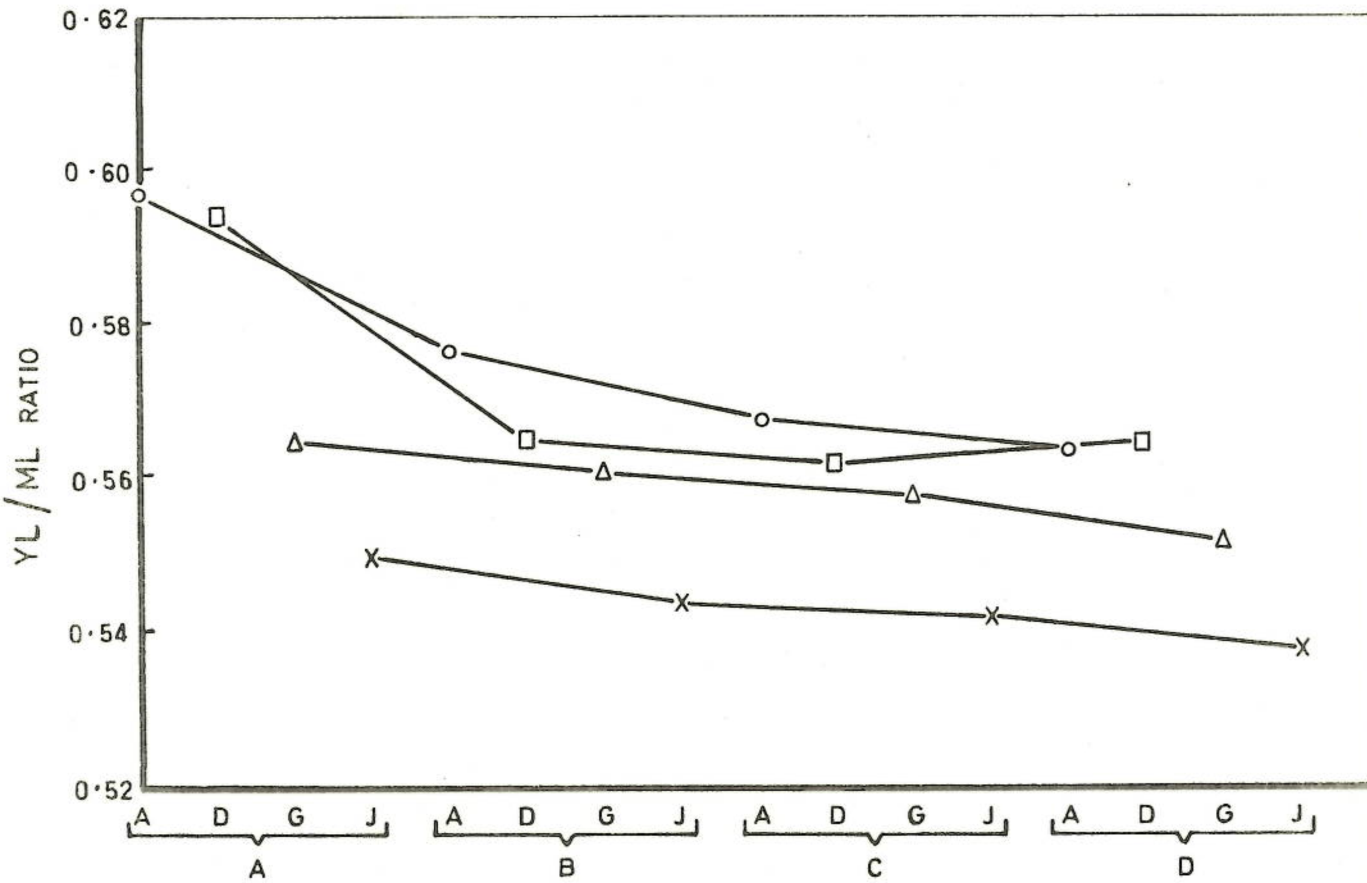


Figure . 6 .

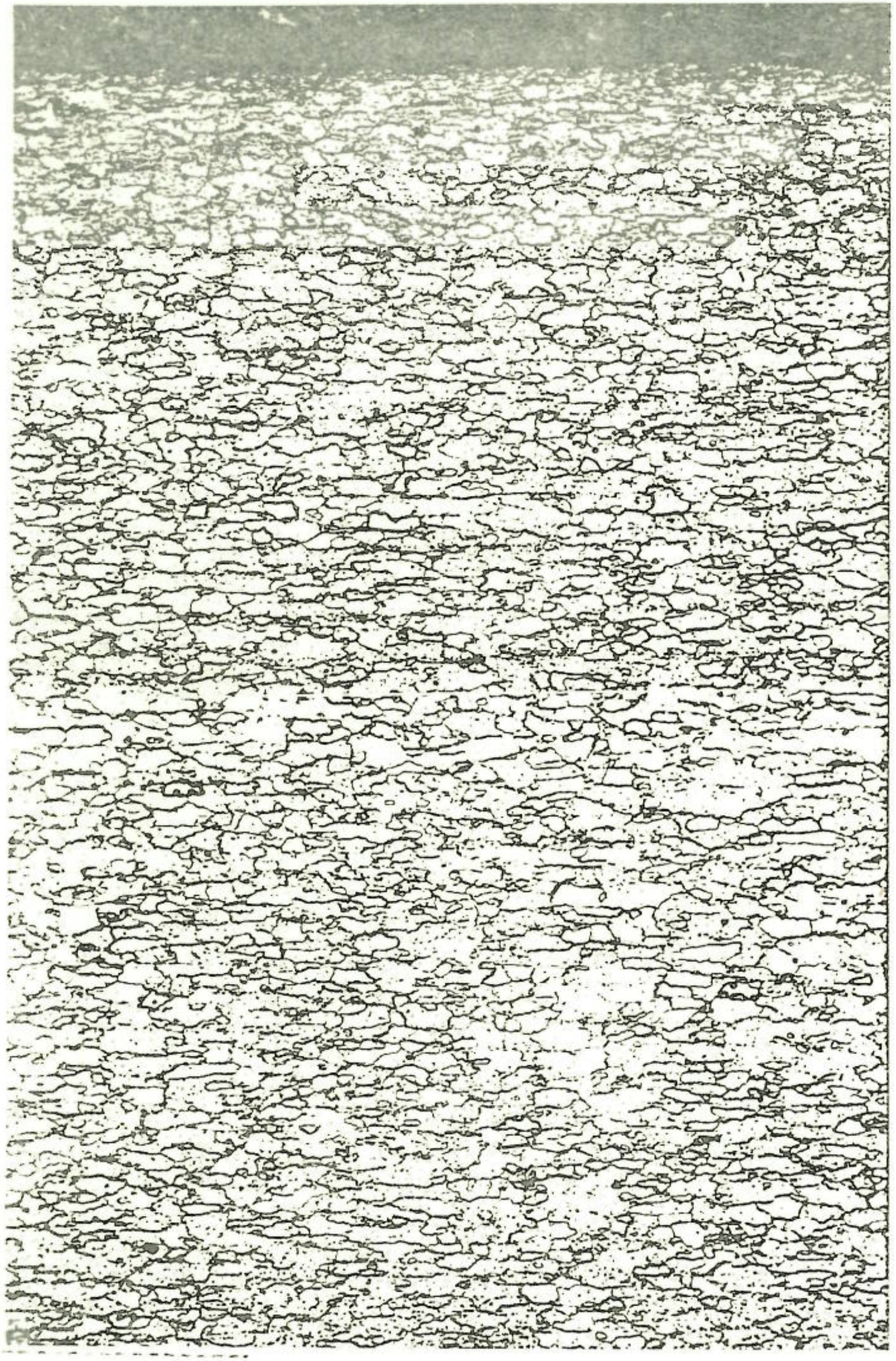


Figure 7 Mag: X 160

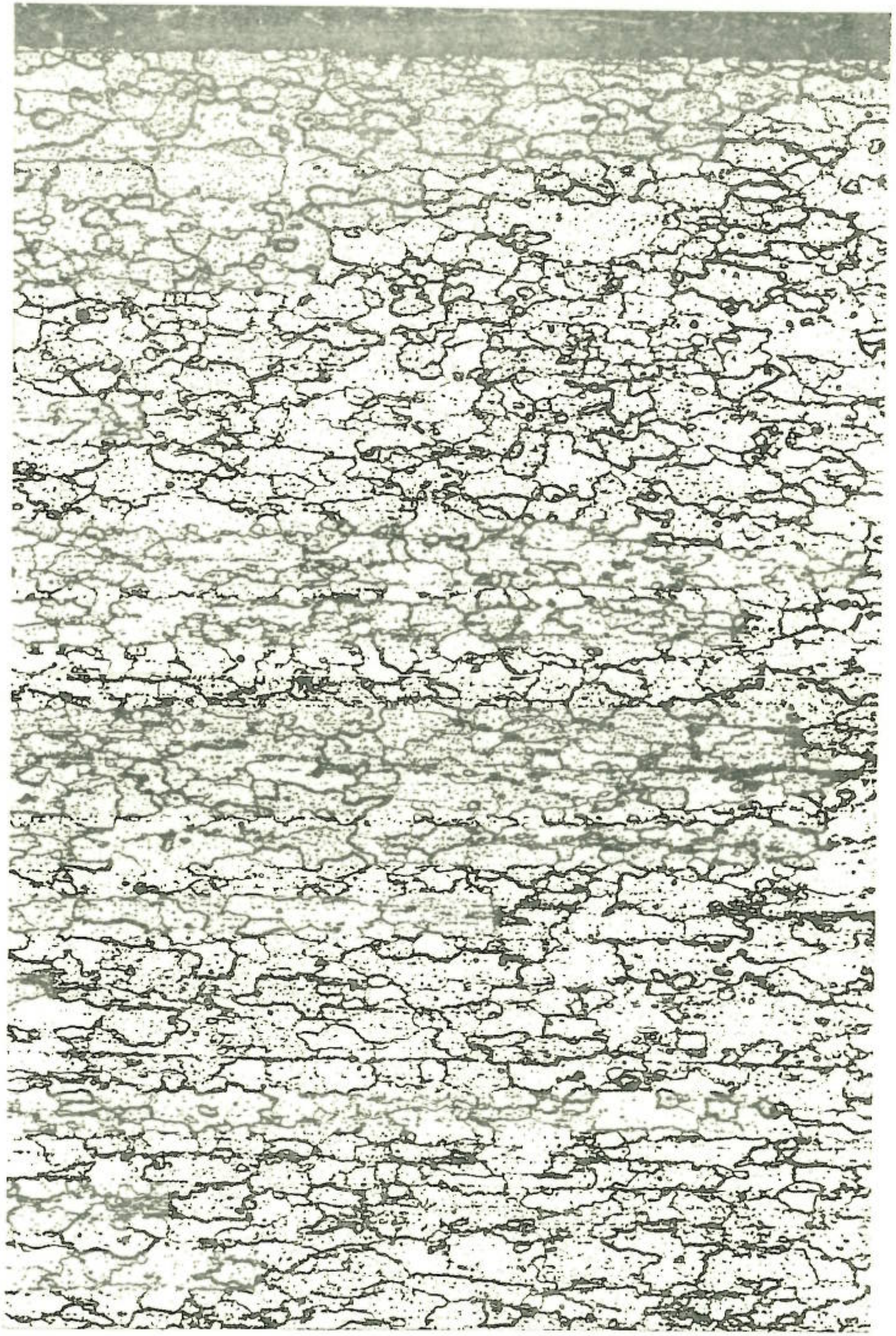


Figure. 8. Mag: X 160

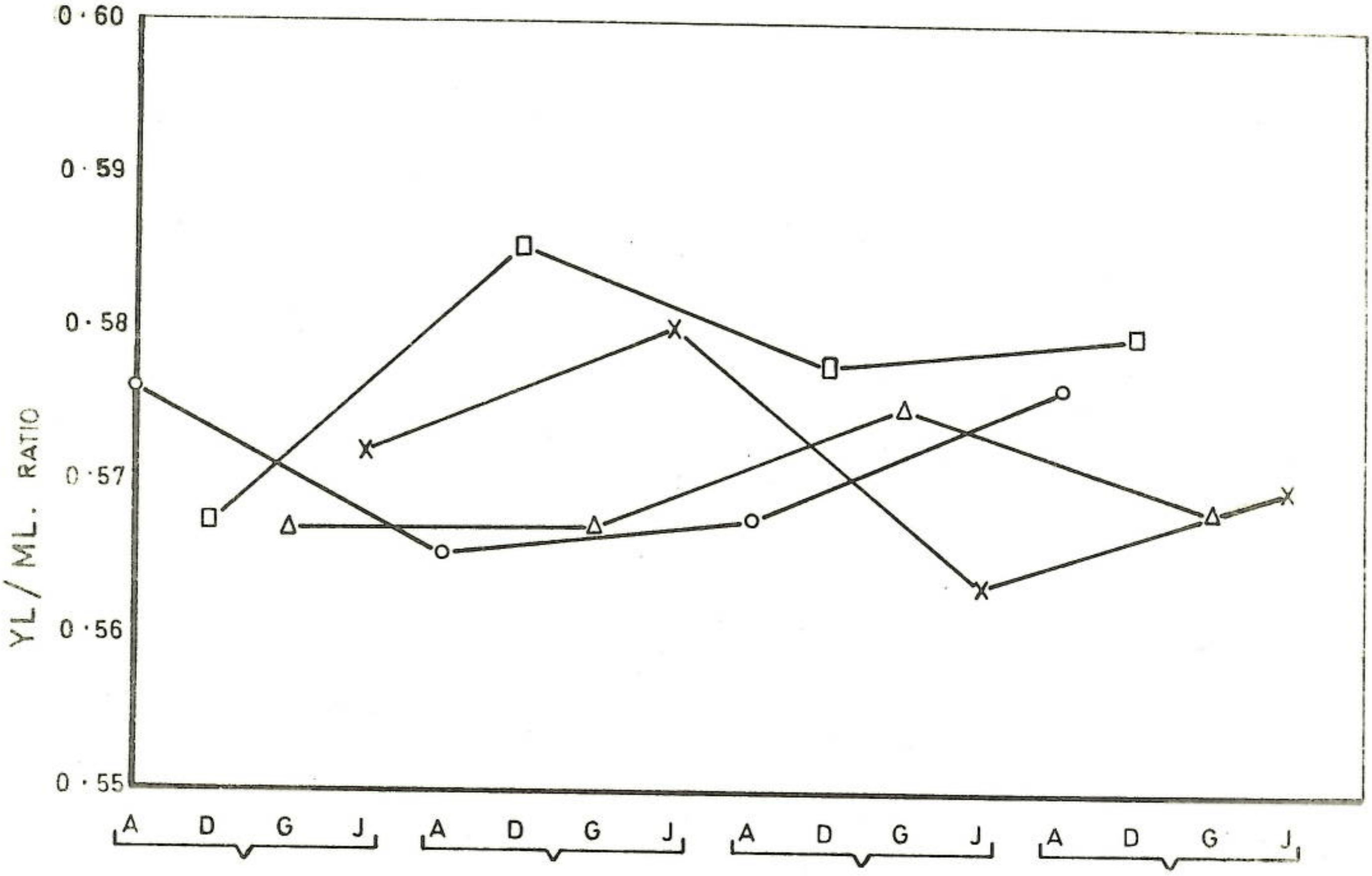


Figure ..9 .

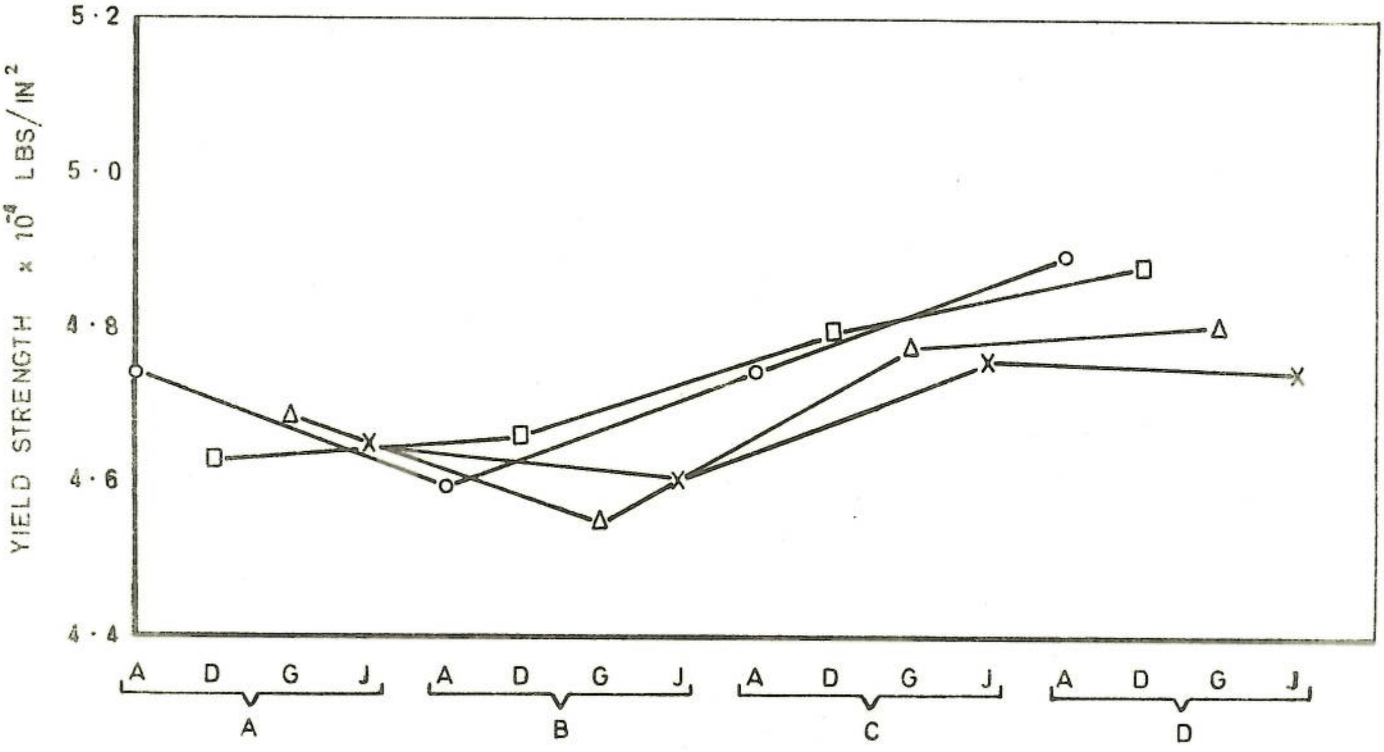


Figure . 10.

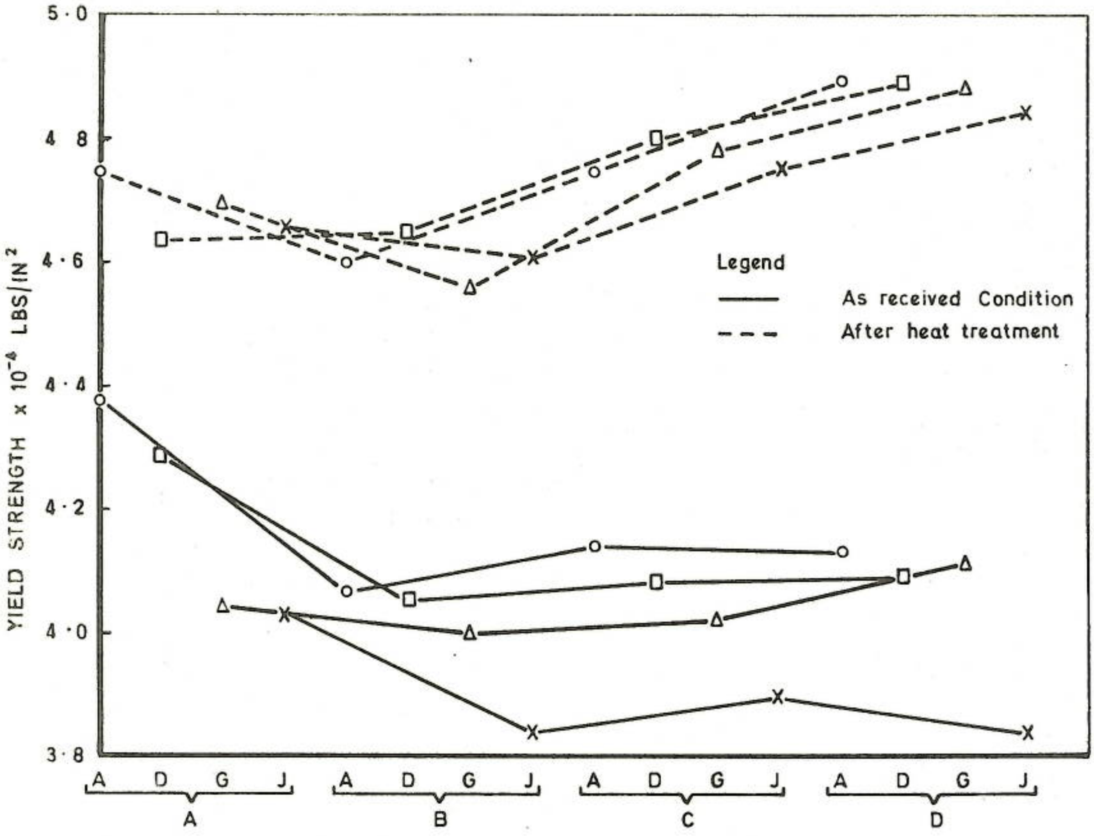


Figure. 11a.

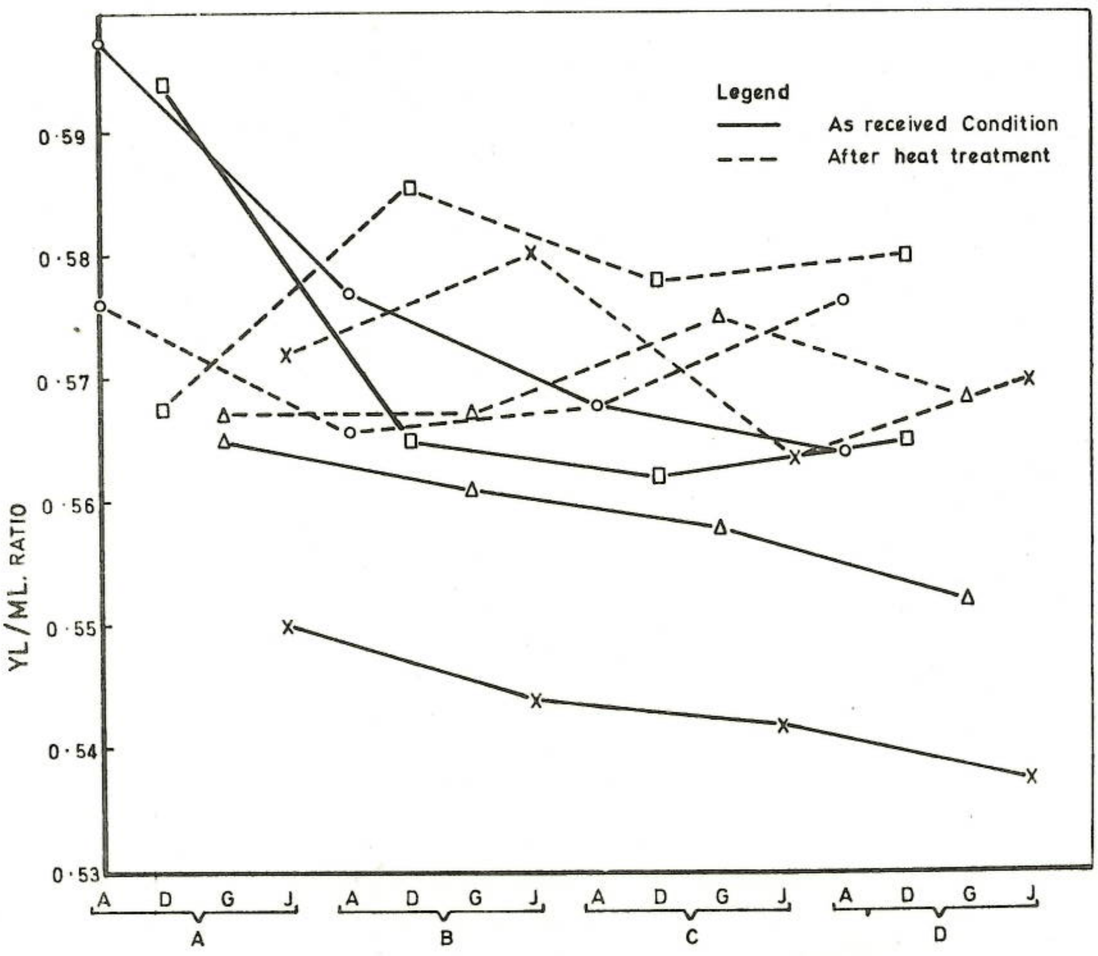


Figure. 11b.

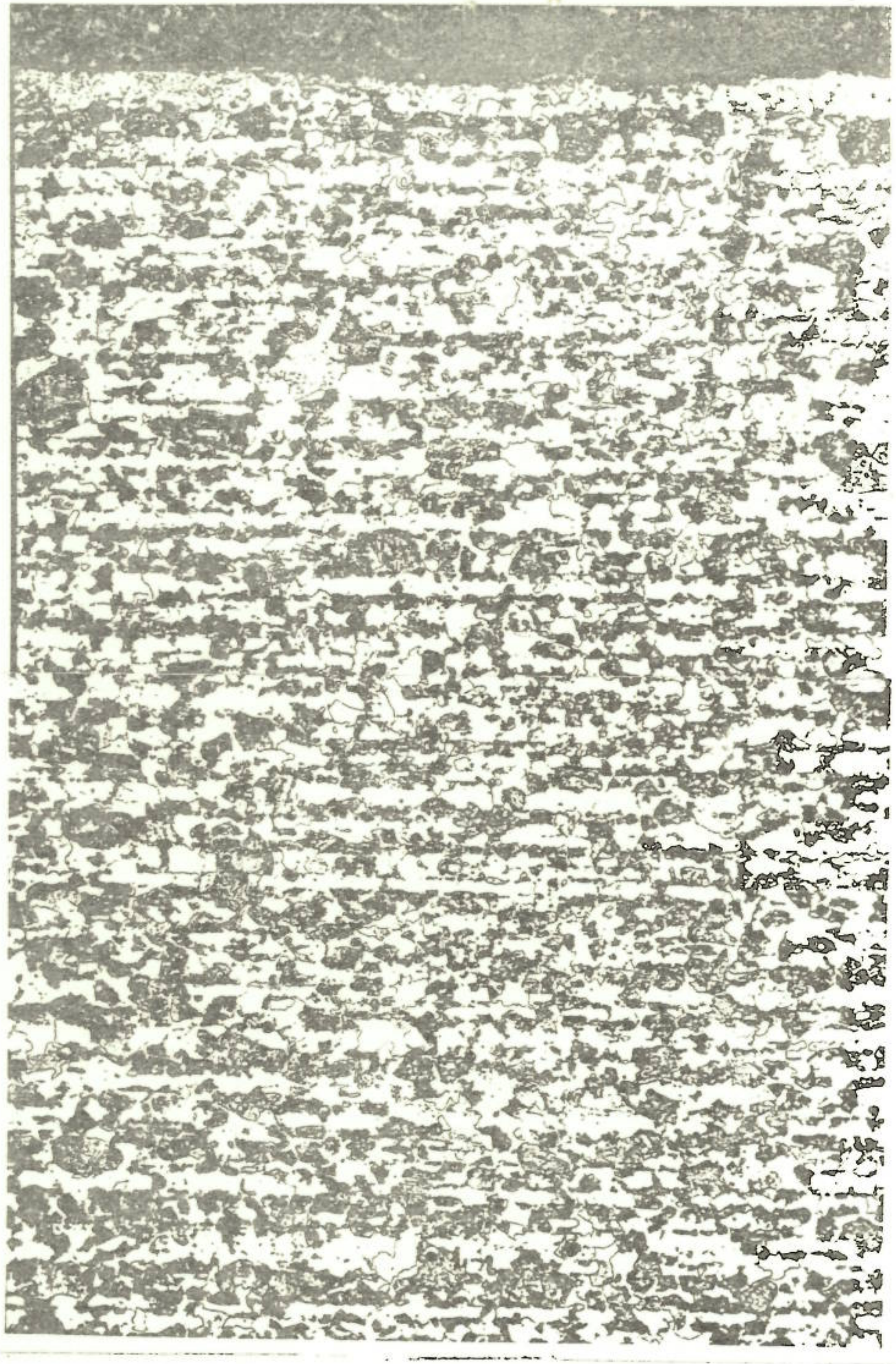


Figure. 12. X 160

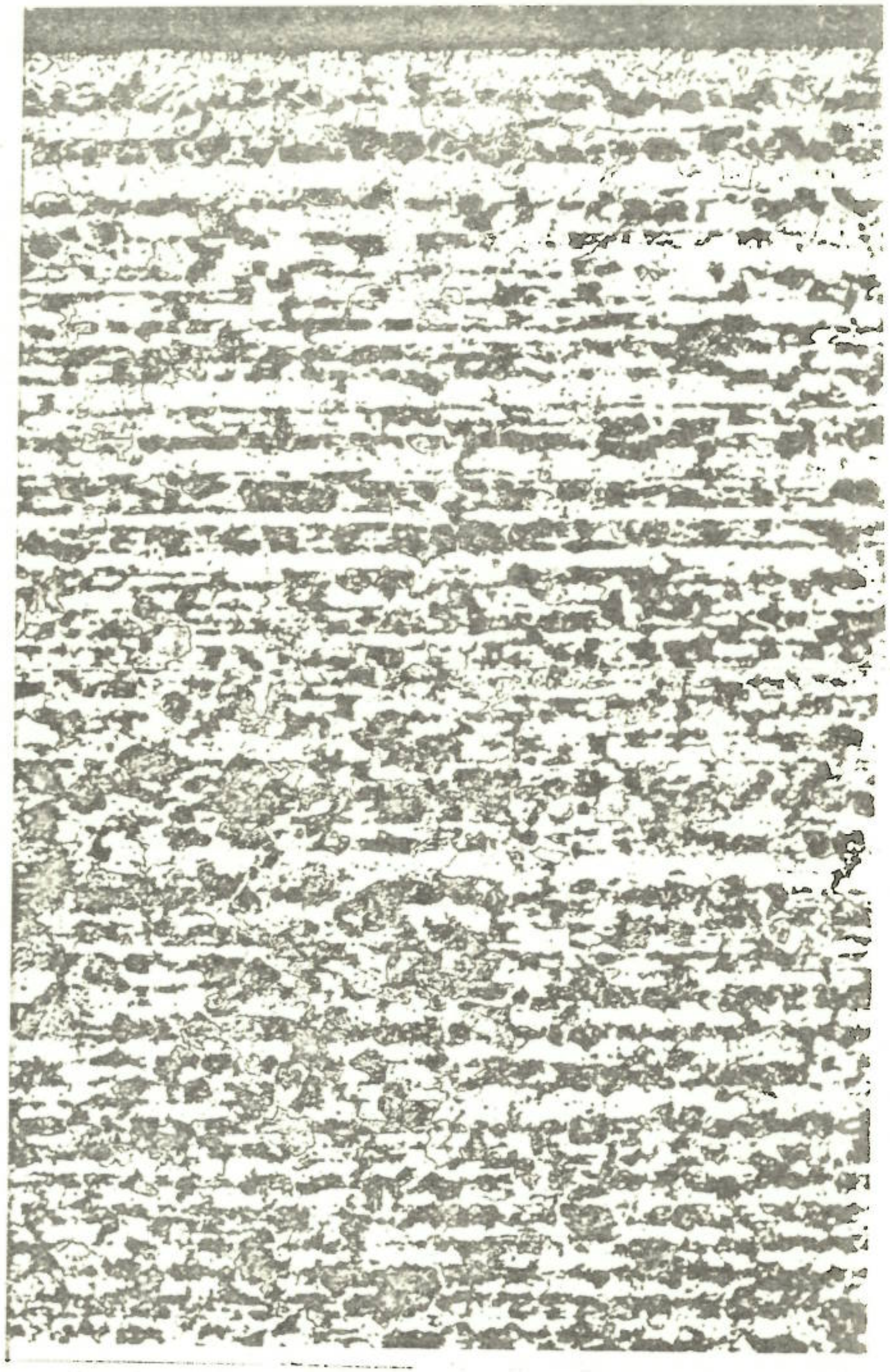


Figure. 13. X 160