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Some aspects of electro-chemical grid-marking

- by -

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Introduction

The value of fine grids, electromarked (1) on to metal sheets before pressing, so that the type and magnitude of the strain developed in the critical region of the pressing can be assessed, is undisputed. Keeler (2), Heyer and Newby (3), and Goodwin (4), have all discussed practical applications of this technique and Palmer (5) has reviewed the field and introduced the concept of a relative safety factor (RSF). However it may be useful to see what this 'mark' consists of, how the marking affects the subsequent metal performance, what the limitations of the process are and other peripherical issues. It is these aspects of the process which is the concern of this paper.

The Mark

The mark can be caused by an AC or DC current. In the former case, the metal is dissolved during one half of the cycle, oxidized, and plated on the clean surface during the second half of the cycle. On steel, then, the mark is iron oxide, (dark in colour) while on aluminium, aluminium oxide is formed, which is white. In both these cases, the mark is, naturally, slightly raised above the surrounding metal surface. The claimed (1) depth of mark is 0.0001 inches. The steel mark is shown in Fig. 1 at a magnification of 300 times. In the DC case, the work is made the anode, and so only dissolution of the metal occurs. In the case of aluminium this produces a black mark, apparently similar to that of steel (AC) but on inspection this resolves into a series of shallow pits, appearing black because of the lack of reflected light from the pits. This is shown, also X300 in Fig. 2. There are obviously no problems of adhesion of the mark in the latter case, and in the former, the oxide adheres strongly to the metal even during rolling (Figs. 3 and 4 mag. X15). The aluminium is shown before (Fig. 5) and after (Fig. 6) bulge testing at the same magnification. Naturally the mark extends with the material and so the question of which is the fiducial mark from which the strain measurement is made becomes more and more important.

The Stencils

Stencils can be made of various materials and by various processes, depending to some degree on the accuracy required. A PVC plastic film stencil, in which the holes can be sparked or produced mechanically is shown in Fig. 7 (X25). The region shown is the junction of a square grid, the squares containing 0.1 inch diameter circles. The thickness of the pierced line and the merging of the circles and squares should be noted. Fig. 8 (X25) shows a stencil produced from a paper, i.e. a material made from random - oriented fibres, impregnated with a red plastic material. The stencil is produced by the removal, probably by dissolution, of the plastic, according to an original master.

The third type of stencil is that made from a woven nylon material, impregnated as above, and shown (X25) in Figures 9 and 10. Here an interesting fault is brought to light. When the pattern required is 'in phase' with warp or weft of the fabric then no pattern is produced. The disappearance of the cut-out with orientation is seen in Fig. 9 while the complete absence of part of the square grid is seen in Fig. 10.

The Electrolyte

Many proprietary electrolytes are available, but many of these are stated to be suitable for etching a range of different materials. A basic solution composed approximately as follows:

Potassium chloride	80 grams
Sodium chloride	90 grams
Nitric acid	100 ml
Hydrochloric acid	100 ml
Water	4.5 litres

has been found satisfactory on ferrous and many non-ferrous metals. The addition of a non-foaming detergent would probably be advantageous for industrial (as opposed to research) use, where careful prior cleaning of metal is not easy. An important point covering the electrolyte is that it should only be in contact with the metal through the stencil to the desired pattern. Thus leakage or seeping of the electrolyte beneath the stencil should be avoided. This is effected by pressing the stencil firmly against the work; Keeler recommends a pressure of 250 - 300 lbs. on a 10 x 10 inch pad, and there are claims that modifications to the electrolyte viscosity will ensure good 'sealing'.

Accuracy

An accuracy, using the paper stencil of ± 2% is not unreasonable to expect, taking into account the variation in line thickness, slight diffuseness in measurement after deformation and line broadening which occurs, though some workers claim that a resolution of 100 lines/inch is possible and a 0.05 in. diameter circle array can be measured to 1%. Fig. 11 shows Fig. 1 with a 1/100th-line grid overprinted with the mark of approximately the same thickness. It would seem that, unless a way is devised of producing a finer line, this claim is slightly exaggerated.

Pressing performance

No evidence has been accumulated which would suggest that this process causes premature failure in pressing and studies of fractures do not suggest that they initiate from a mark or propagate along them. Further, a report on the effect of electromarking on corrosion and fatigue behaviour of a range of aluminium alloys (6) concludes that it does not adversely affect either of these properties.

Conclusions

This is an excellent process with few limitations. It can be used in the laboratory for gridding tensile test-pieces before extension and for gridding coupons before simulative testing. In the press-shop it can be used for marking blanks before pressing to assist die tryout, or to rank a 'difficult' heat-number of steel during a press run. The only press-shop requirement is an electric socket reasonably near the press and a 'bridge' over the stencil-holder so that weight can be applied. This can be done by the operator standing on the rig!

The question of accuracy and fineness of line should be resolved. The limiting feature appears to be the fibre size in the cloth. A plastic film has a much smaller 'fibre' size, (i.e. the diameter of the molecular chain) but the process at present in use seems incapable of making a fine line in this material.

The matter of measurement has still to be studied, for the individual measurement of several hundred tiny ellipses can be tedious. On the other hand, any automatic method which would take into account the curvature of a complex pressing would, if practicable, be sophisticated and expensive. Nevertheless, with the few limitations outlined above, the usefulness of this process is firmly established as a part of sheet metal deformation studies.

References

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3. Heyer, R.H. and Newby, J.R. Factors in selecting materials for forming. Metal Progress, 1967, 91, 3, 85.

4. Goodwin, G.M. Application of strain analysis to sheet metal forming problems in the press-shop, SAE, 1968, 680093.

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6. Electrochemical marking. The de Havilland Aircraft Co. Ltd., Report No. EA292C/60, September, 1960.

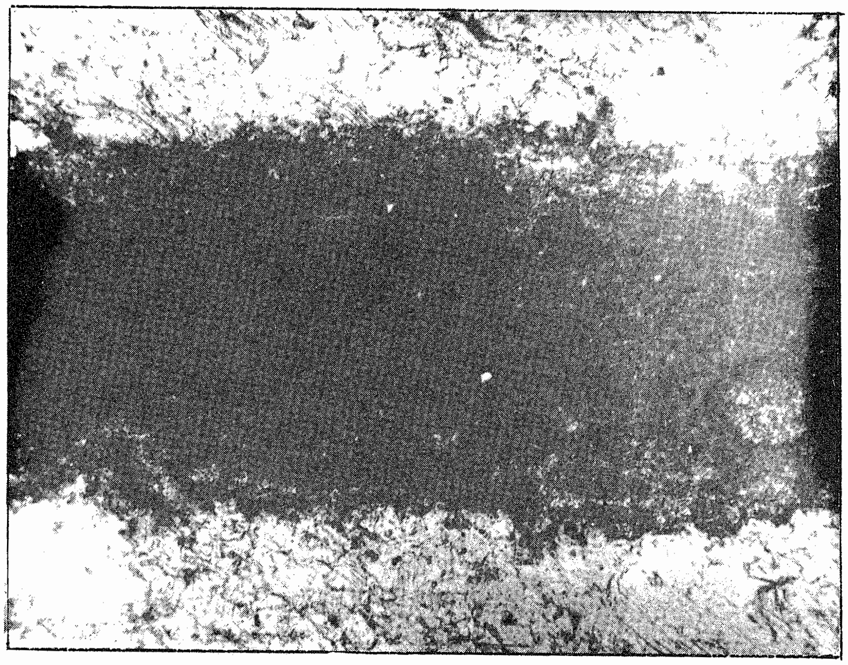

FIG. 1 e. d. d. STEEL ELECTROMARKED WITH AN A. C. GRID (X300)

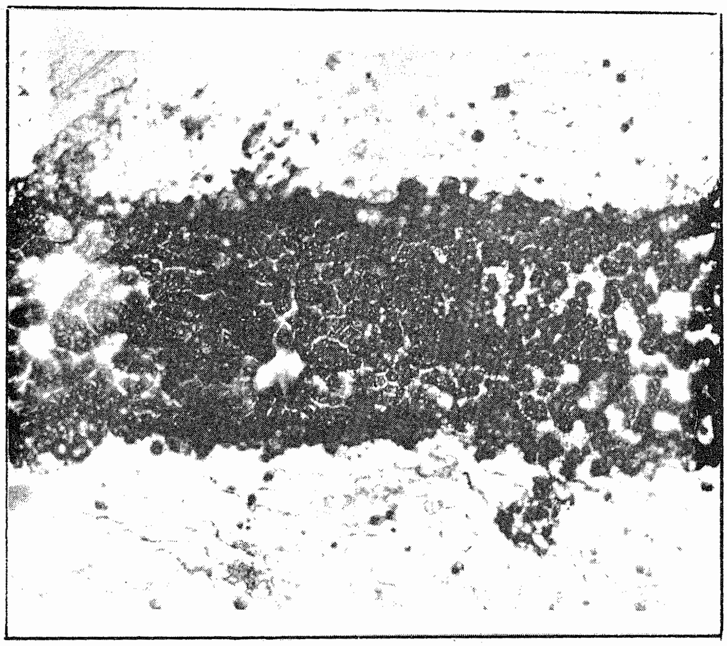

FIG. 2 c. p. ALUMINIUM SHEET SINGLE CRYSTAL ELECTROMARKED WITH A D. C. GRID (X300)

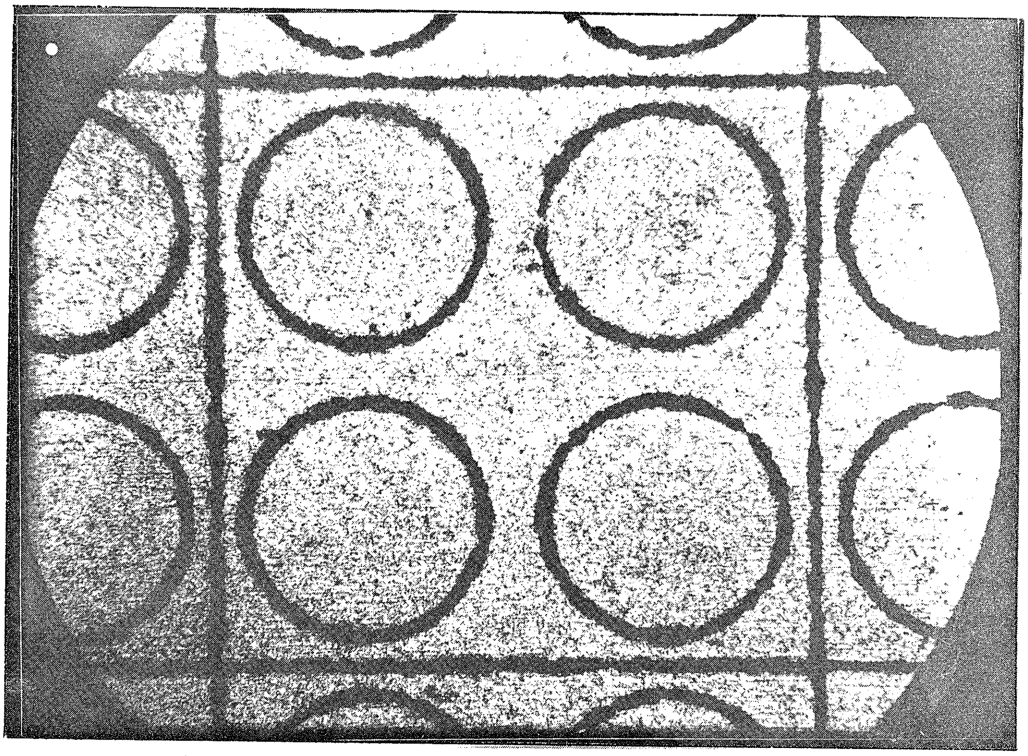

FIG. 3 GENERAL VIEW OF STEEL GRID, UNDEFORMED (X15)

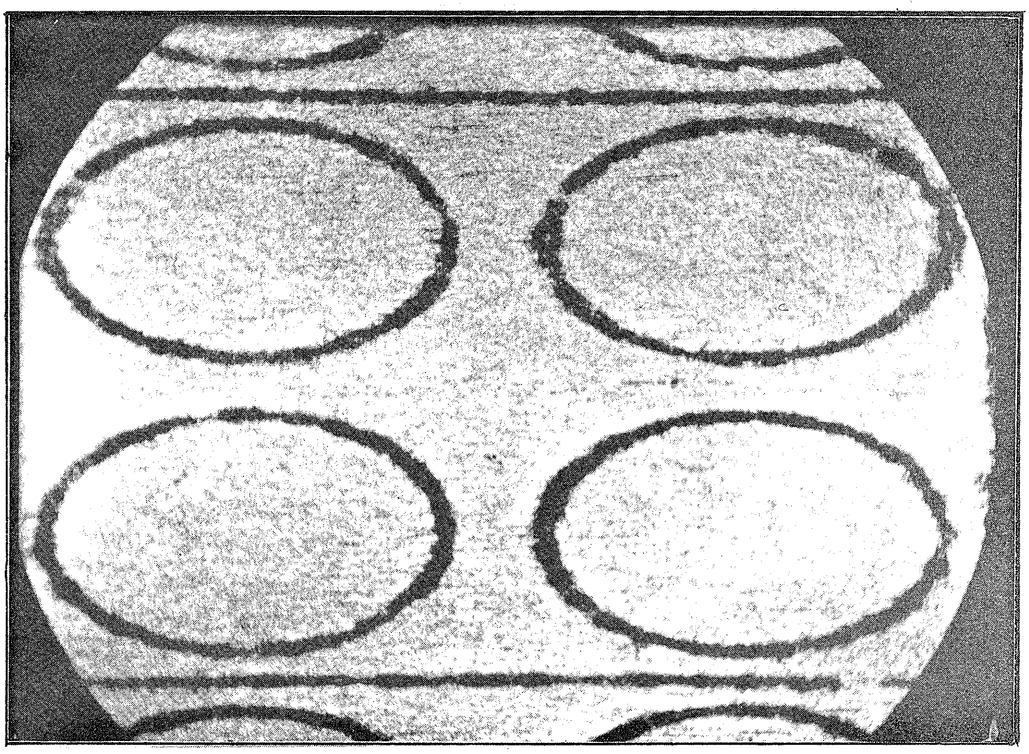

FIG. 4 GENERAL VIEW OF STEEL GRID AFTER COLD ROLLING (X15)

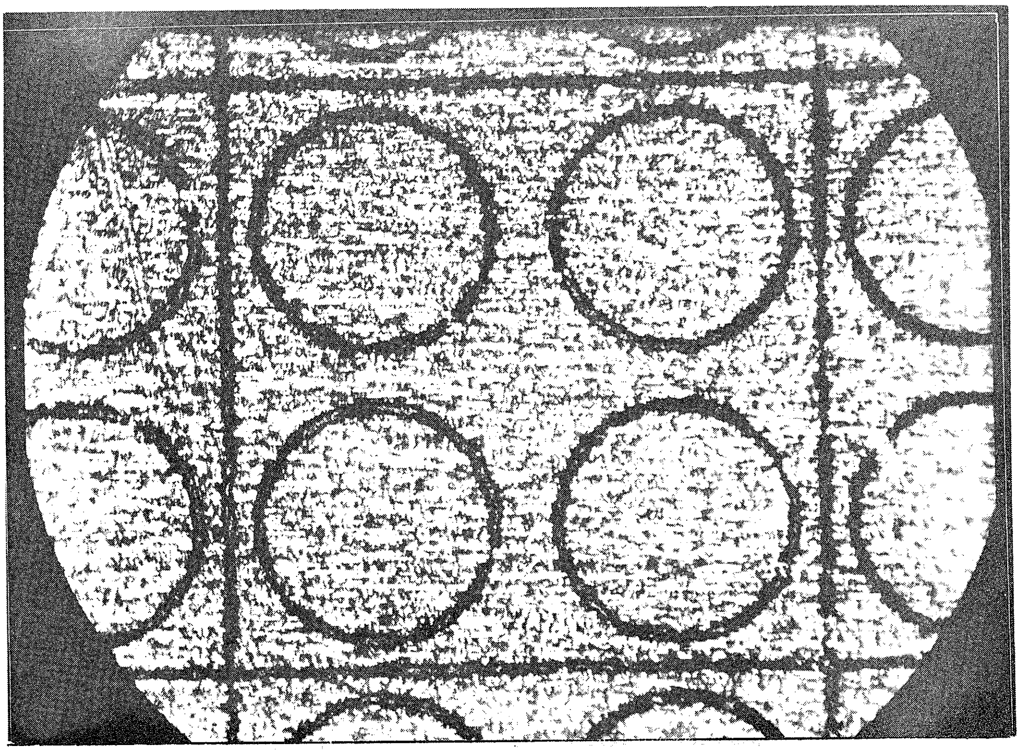

FIG 5 GENERAL VIEW OF ALUMINIUM GRID, UNDEFORMED (X15)

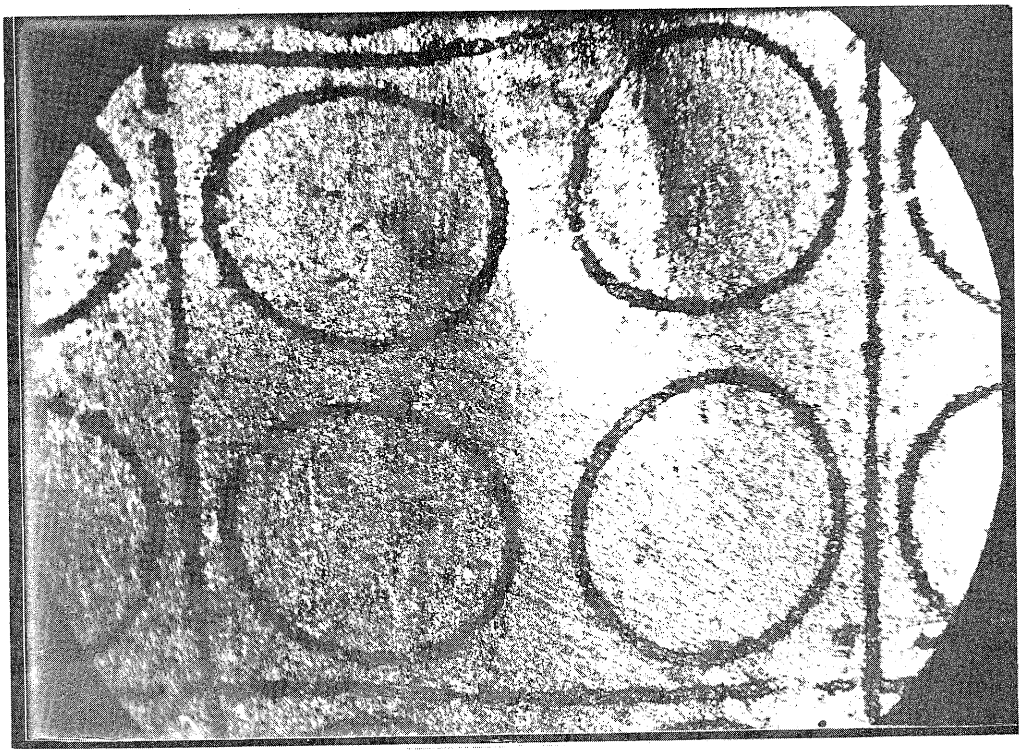

FIG. 6 GENERAL VIEW OF ALUMINIUM GRID AFTER BULGE TESTING (X15)

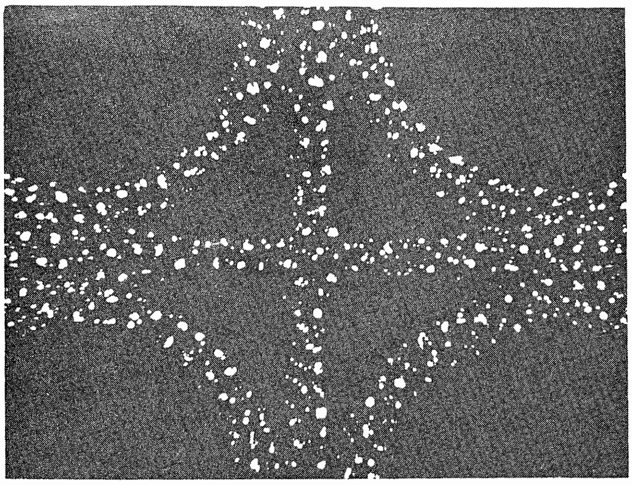

FIG. 7 STENCIL MADE FROM PVC FILM (X25)

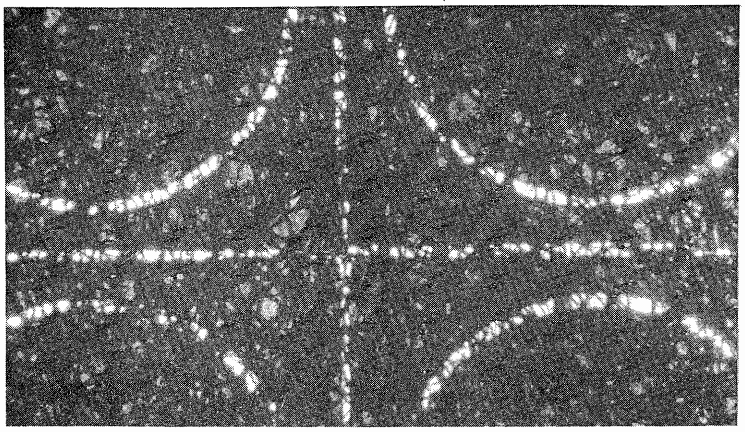

FIG. 8 STENCIL MADE FROM PLASTIC-IMPREGNATED PAPER

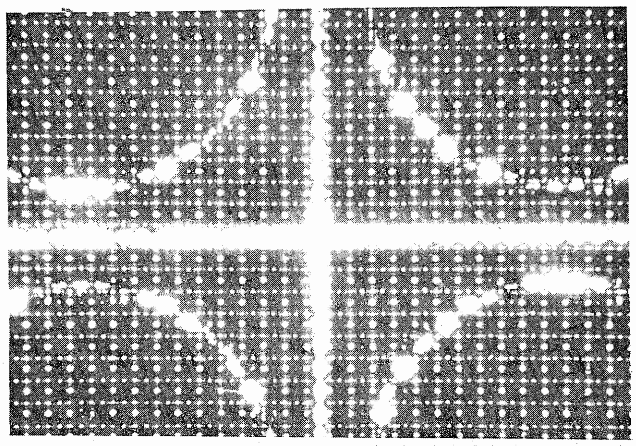

FIG. 9 NYLON STENCIL. THE SQUARE GRID CAN BE SEEN, BUT CIRCLES ARE DISCONTINUOUS DUE TO ORIENTATION EFFECT

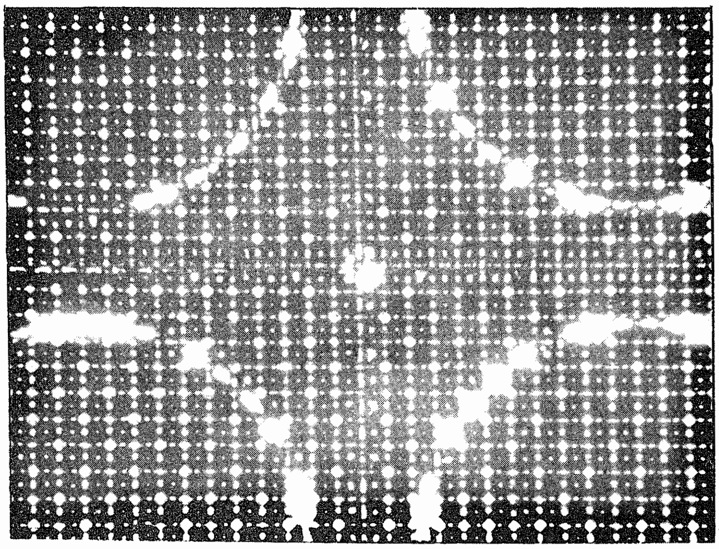

FIG. 10 NYLON STENCIL. THE SQUARE GRID HAS NOT BEEN CUT AS IT IS IN PHASE WITH A FILAMENT

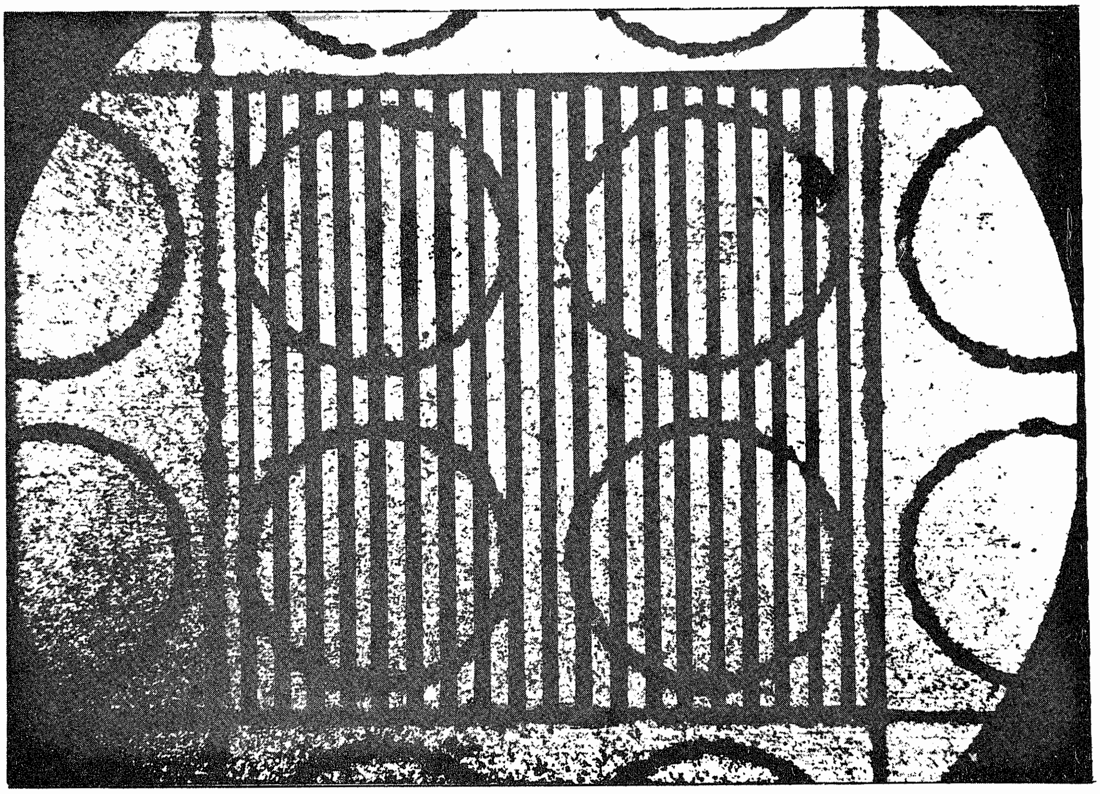

FIG. 11 AS FIGURE 3, BUT WITH A 0.01-INCH LATTICE SUPERIMPOSED