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by

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REGISTRATION TECHNIQUE FOR MULTILAYER THICK FILM WORK

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ABSTRACT

A novel registration system has been devised around special registration marks which enable alignment of out-of-contact planes and eliminate the use of a low-power microscope while retaining accuracy compatible with thick film work. These special registration marks are based on circular grids which generate Moire patterns when superimposed. The accuracy of this registration system is built-in at the pattern design stage eliminating operator judgment. Operators can be trained in a matter of minutes. The technique can readily be extended to the graphic arts and related electronic manufacturing techniques with savings in labour and improved accuracy whenever two layers should be registered.

REGISTRATION TECHNIQUE FOR MULTILAYER THICK FILM WORK

PRIOR KNOWN ART

The current common registration practice relies on trial and error printing. The operator aligns features from a previously printed layer with features from the current layer. Fiducial marks are rarely used since little is gained in accuracy with respect to the space occupied. The registration quality is evaluated under a low power microscope after each registration attempt. Corrections and new trials are made until satisfactory registration is obtained. While manufacturing the screen stencils the pattern is grossly positioned with respect to the screen frame. The only concerns are that the pattern must fall within the position adjustment tolerances of the substrate holder and proper alignment between the screen mesh and features in the pattern for proper reproduction of fine details. The tolerances in mounting the screen frame on the machine must also be taken into account in the course of the gross positioning.

Since from the initial artwork to the ceramic substrate no fixed reference point is used in space, the multiple pattern image transfers registration accuracy relies on the operator judgment and skill. A number of substrates must be used during the repeated attempts, the exact number depending on the operator skill, thereby decreasing the yield if the substrates are discarded or increasing the labour cost if the substrates are reclaimed.

Attempts have been made to ease registration difficulties by pre-registering the pattern with respect to the screen frame. One method recently described by Honeywell-Bull workers(1) requires accurate machining or insertion of locating pins on the screen frames. These modified screen-frames are a serious disadvantage especially for the smaller plants acquiring their screens mounted on frames from outside sources.

NEW REGISTRATION SYSTEM

A novel registration system has been devised around special registration marks which enables alignment of out-of-contact planes and eliminates the use of a low-power microscope while retaining an accuracy compatible with thick-film work.

A set of registration marks is placed permanently on the machine while a matching set is imaged on the screen. Both sets are brought in registration with the usual machine adjustments. No modifications are made to the equipment other than affixing a permanent set of registration patterns and a means for transilluminating them.

The registration system is schematically illustrated on Figure 1. A registration pattern is shown in Figure 2. The system relies on the Moire pattern generated when a small displacement is introduced between two superimposed registration patterns.

(1) K. Kurzweil, P. Siegel "Thick Film Registration Made Easy" 1972 International Hybrid Microelectronic Symposium, Washington, D.C. (1972).

The theory of fringes formation in gratings, and in particular gratings consisting of equispaced concentric circles, can be found elsewhere (2-4). The particular gratings used consist of two grids with slightly different pitch. When the grids are superimposed qualitative and quantitative information can readily be derived from the Moire pattern. Because small displacements in relation to the size of the pitch causes large Moire effects an optical leverage is readily obtained hence obviating the need for visual aids such as a low power microscope. The number of fringes passing through a common point is directly proportional to the number of half-pitch distances separating the centre of the concentric circles as shown in Figure 3. When the distance separating the centres is less than half-pitch width a single fringe is formed around the centres. When the grids are exactly concentrics the Moire fringe becomes a circle which is also concentric to the grid patterns. The diameter of this circular fringe is determined by the difference in pitch in the superposed grids. The ultimate accuracy of the system is then determined by design with constraints brought by the allowable registration mark size and the visibility of the fringes i.e. fringe contrast. Figure 4 illustrates these points. Examination of Figure 3 clearly shows that the centre of the grids lies on the axis of symmetry hence an indication of the direction of motion is given to bring quick registration between the grids.

An attractive feature of the Moire pattern registration method is that the operator can be unaware of the ultimate accuracy of the system and its quantitative features and can learn in a few minutes to register accurately by intuitive feel.

OPTICAL DESIGN CONSIDERATIONS

In this particular application the constraints are the visual acuity of the operator's unaided eye i.e. the limitation on the minimum width of the pitch, the maximum size allowable for the patterns and minimization of the secondary Moire pattern interference caused by superposition of the circular gratings with the square grating formed by the screen mesh.

The various compromises led to a 10 mils pitch for equal width concentric circles on the larger grating and 9.7 mils for the smaller grating. If we define the criteria for accuracy as perception of decentering in the first fringe by one half-pitch width, then the accuracy of this system becomes .63 mil. In practice the quoted accuracy is easily accomplished. The pitch width was arrived at mainly by compromise with interference minimization between the screen mesh and the circle grids. The adopted configuration has proven acceptable for screen meshes between 80 and 400 lines/inch.

(2) V. Ronchi, Z. Phys. 37, 732 (1926)

(3) P.S. Theocaris "Moire" Fringes in Strain Analysis" Pergamon Press, New York (1969)

(4) M.C. King and D.H. Berry Applied Physics 11, 2455 (1972)

During preparation of the screen stencil, linear accuracy and therefore center to center dimensions between registration marks may vary slightly for example due to differences in camera settings if the camera is not fixed reduction. Assuming that common fiducial marks and a microscope are used to register large inaccuracies can occur if the linear difference is larger than the width of the fiducial marks. With the Moire pattern system no accuracy loss occurs because it merely becomes necessary to obtain symmetrical patterns if two perfect circles cannot be obtained.

ARTWORK GENERATION

In order to avoid generating new registration patterns for each stencil a special template was made to be used at the photographic reduction step. The upper left hand corner of the network pattern is always used as the reference point throughout this thick-film production. A schematic template is shown in Figure 5. The network patterns are generated on prepunched Mylar to dimensions suitable for the metallic registration pins and are mounted on the template prior to the 10 times down photographic reduction. Because quality metallic register pins and punching guaranties registration to better than a mil and because of the photographic reduction leverage factor, very little overall accuracy is lost for large savings in time. Resolution micrographic charts and sensitometric strips are added to provide a ready check on the photographic quality independently of the particular network pattern generated.

CONCLUSION

This novel registration system has proven to be within the overall accuracy sought of better than one mil on the first registration trial and in consistently very short set-up times probably less than two minutes. No special screen frame or other costly factor is involved past the template preparation and the back-illumination set-up on the printer.

JJH:lg
April 23, 1975.

APPENDIX

Resolution and sensitometric patterns for quality control.

a. S.H. Goldsmith, H.D. Lydick 'New Test Target Helps Microphotographers Find Limits of Photographic Systems' Solid State Technology, November, 1971.

b. Anon - 'Using Gray Scales as a Visual Check on Exposure and Development' Kodak Publication PDQ-6 (1972) Rochester, N.Y.

Targets available from Eastman Kodak Co., Rochester, N.Y. 14650 - Microphotographic target, approximately $20.00, opposed gray scales: reflection approximately $6.00, transmission approximately $12.00.

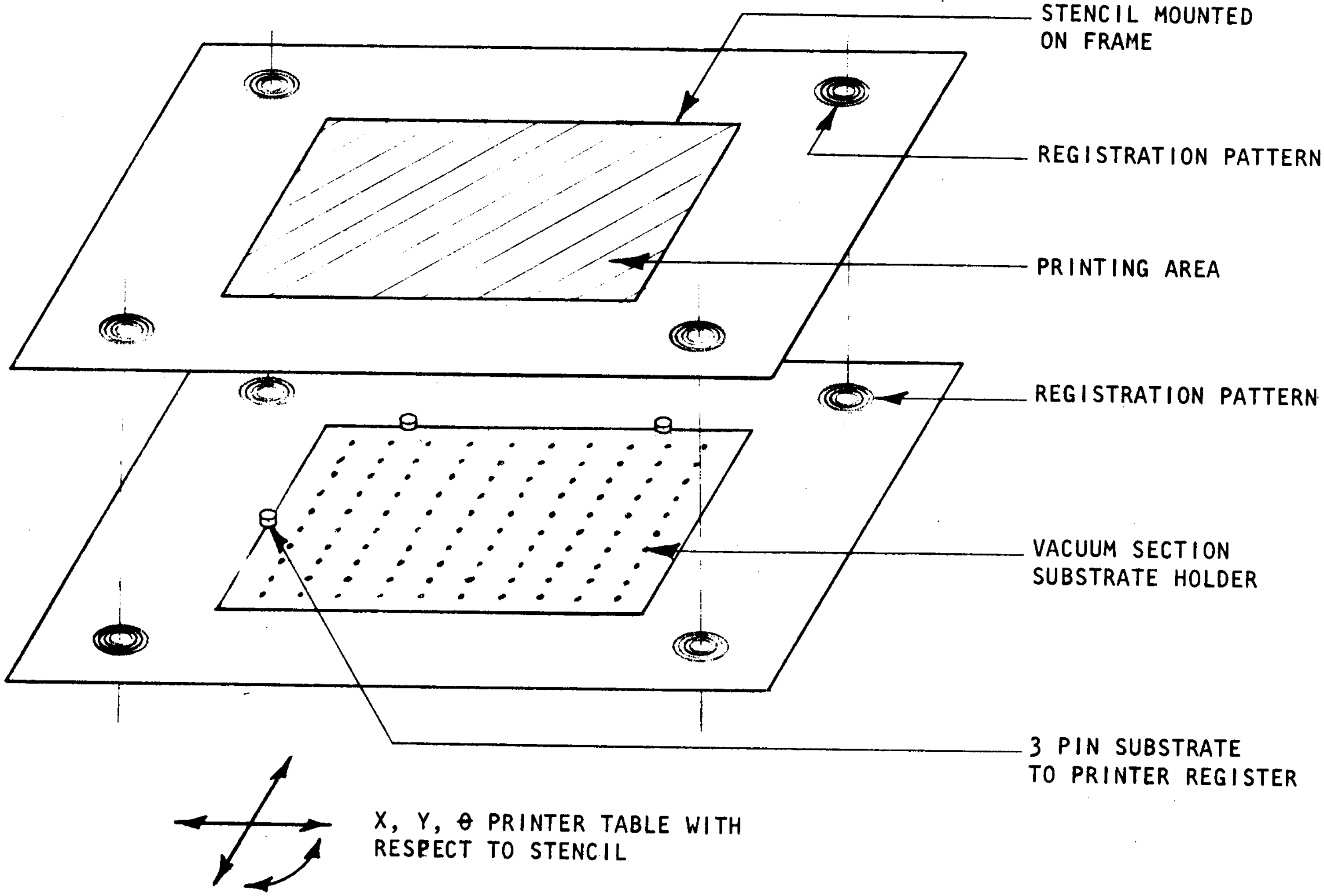

STENCIL MOUNTED
ON FRAME
REGISTRATION PATTERN
PRINTING AREA
REGISTRATION PATTERN
VACUUM SECTION
SUBSTRATE HOLDER
3 PIN SUBSTRATE
TO PRINTER REGISTER
X, Y, θ PRINTER TABLE WITH
RESPECT TO STENCIL

FIG. 1/A

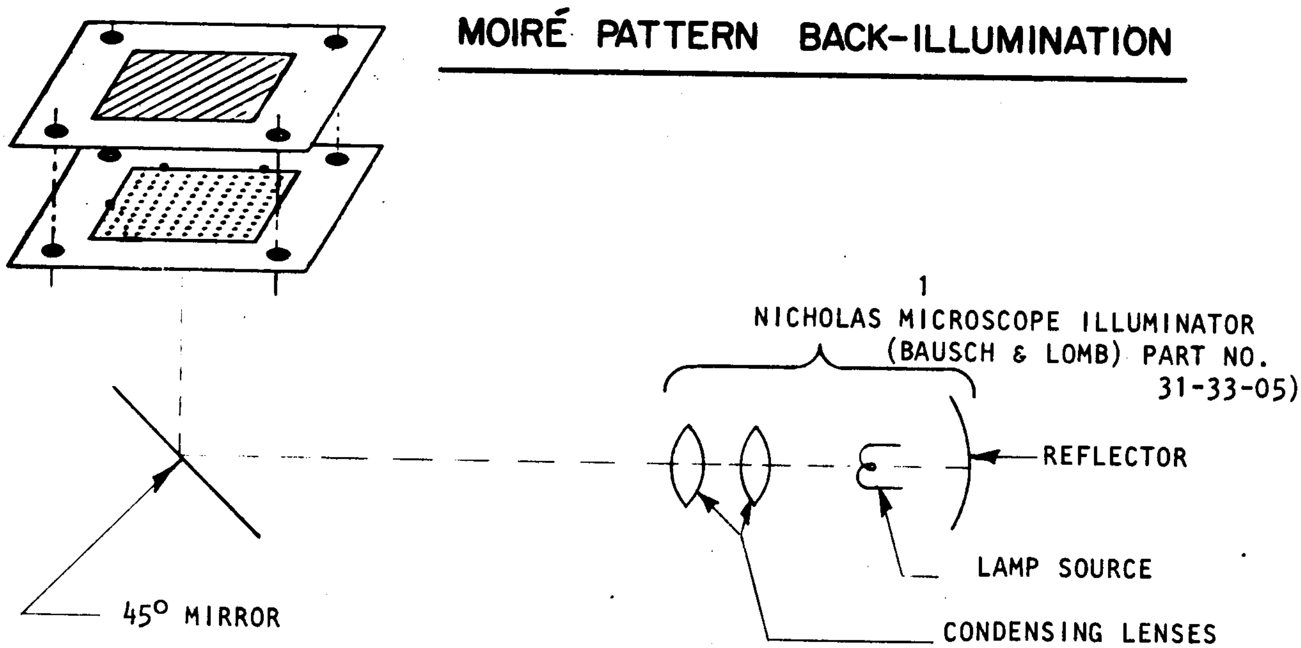

MOIRÉ PATTERN BACK-ILLUMINATION
1
NICHOLAS MICROSCOPE ILLUMINATOR
(BAUSCH & LOMB) PART NO.
31-33-05)
REFLECTOR
LAMP SOURCE
CONDENSING LENSES
45° MIRROR

FIG. 1/B

FIG. 2

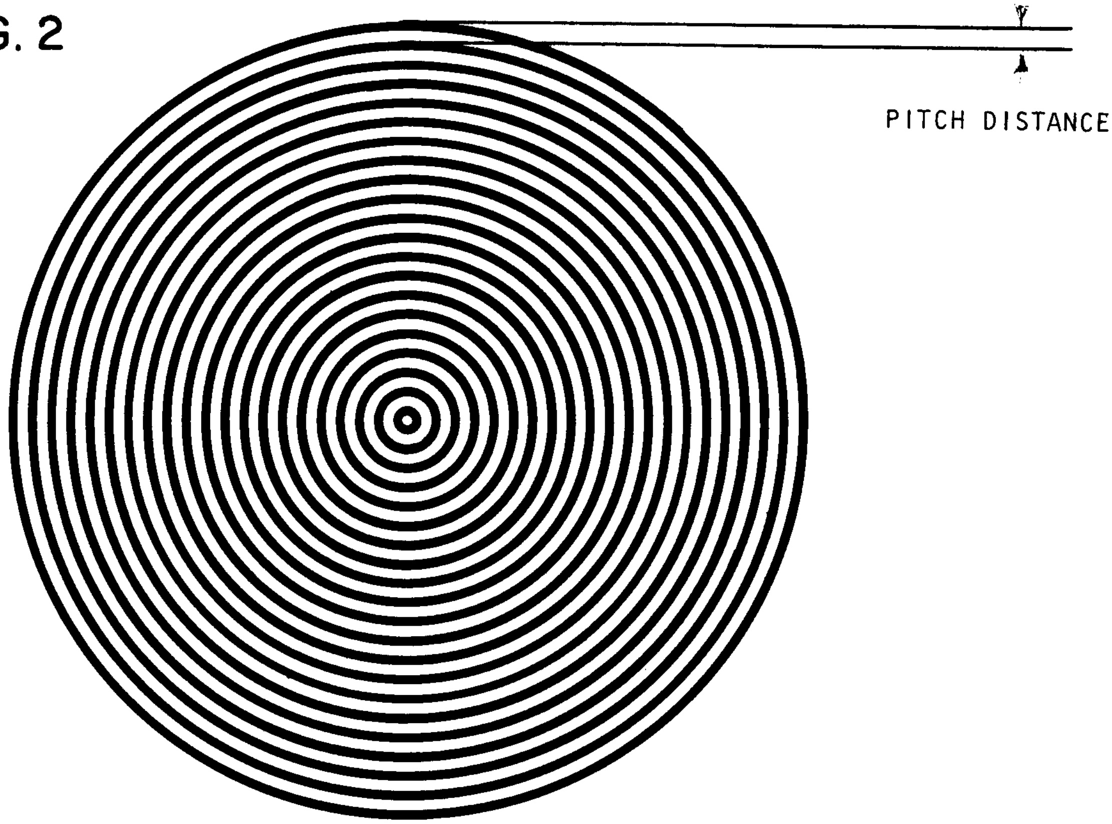
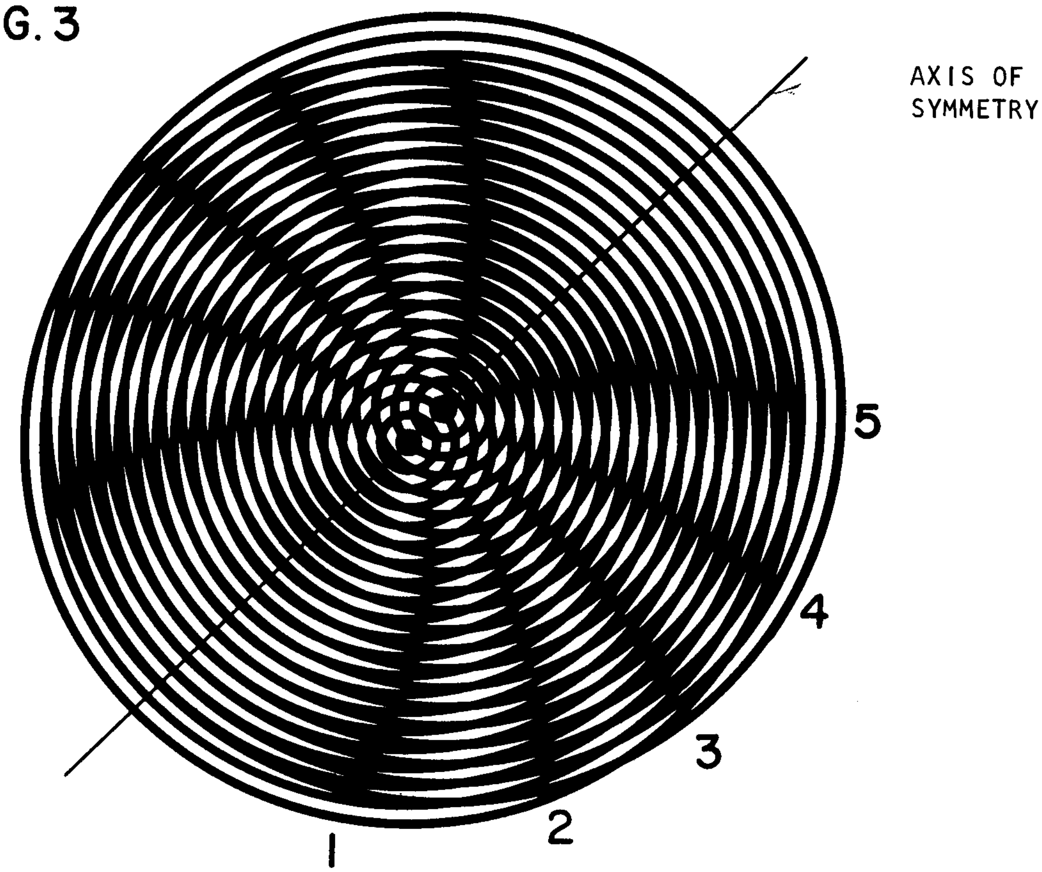
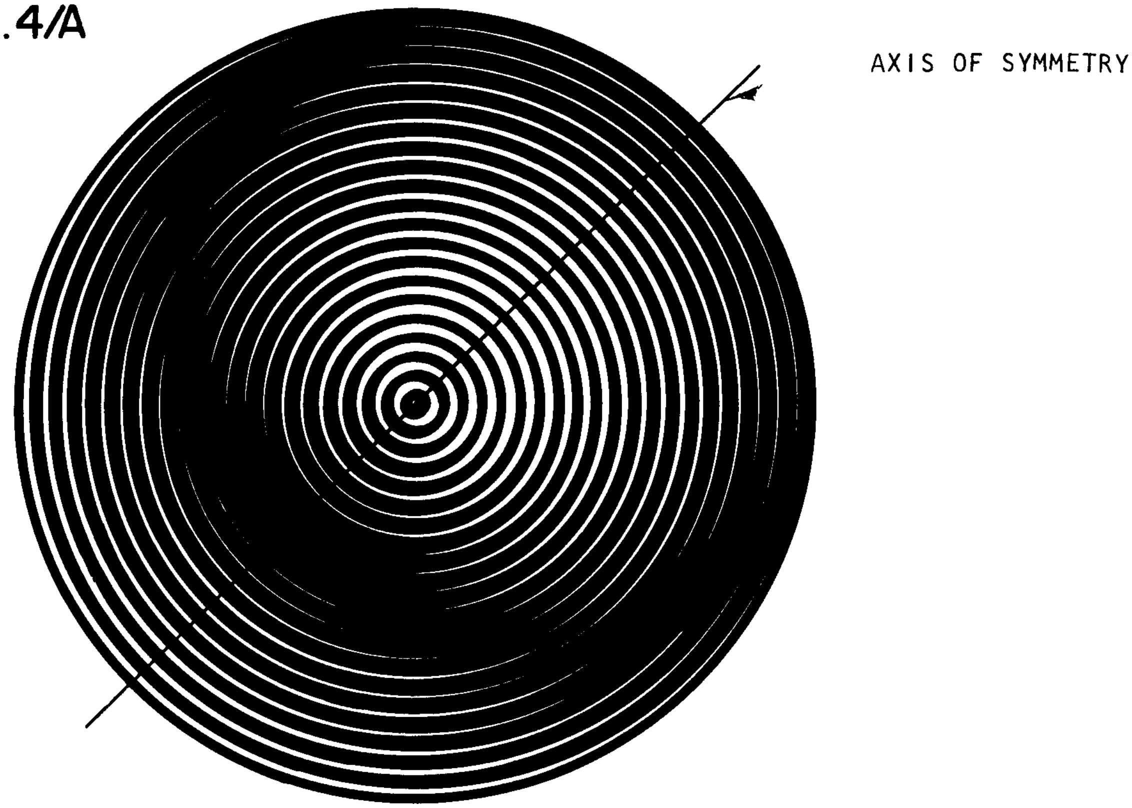


FIG. 3



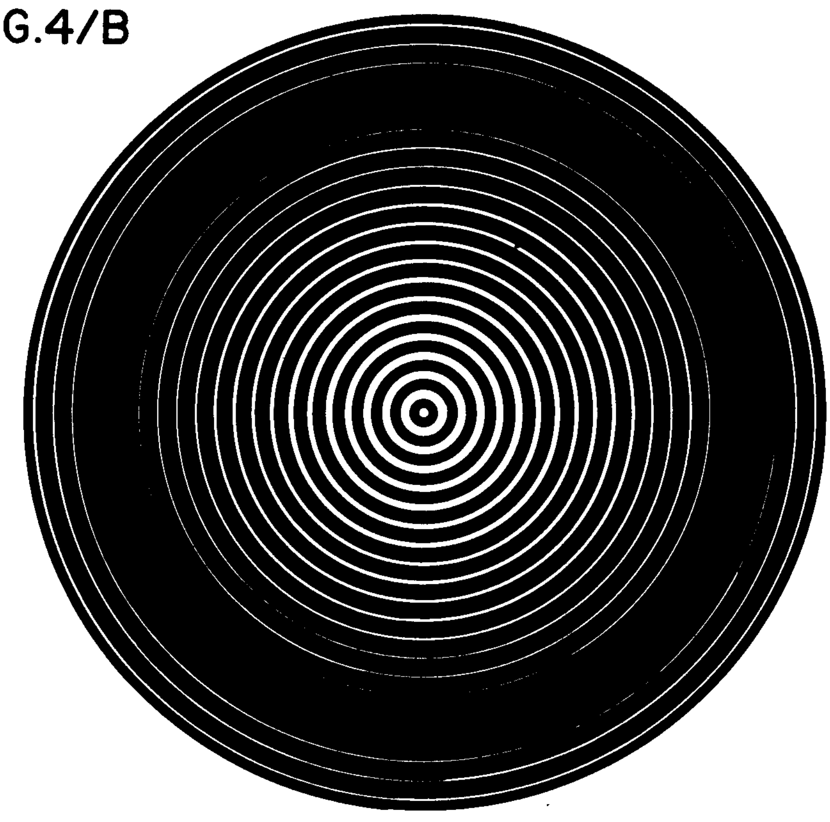
5 FRINGES = SEPARATION OF CIRCLES BY 6 HALF-PITCH WIDTH
MOVING ONE CIRCLE BY THE SEPARATION LENGTH ALONG THE AXIS OF SYMMETRY IN THE SENSE WHICH DECREASES THE NUMBER OF FRINGES WILL MAKE THE CIRCLES CONCENTRIC

FIG.4/A



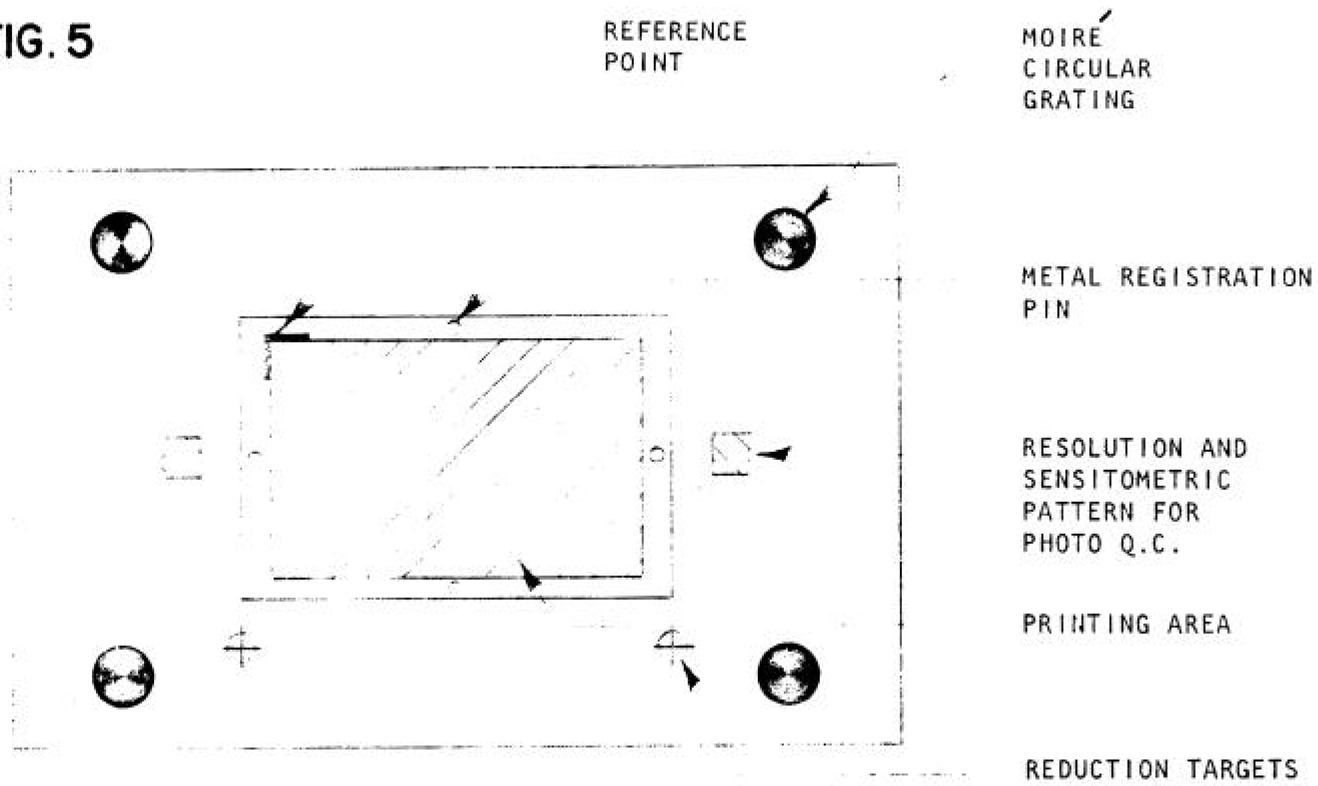
CENTERS SEPARATED BY LESS THAN HALF PITCH (HERE APPROXIMATELY 1/4 PITCH DISTANCE)

FIG.4/B



CIRCLES ARE CONCENTRIC

FIG. 5



ARTWORK GENERATION TEMPLATE