6.3 Angle and Alignment Accuracy Test

The angle and alignment accuracy test for the variable aperture assembly is designed to check the following functions within the system.

1 X and Y stage motion accuracy over the central 40 mm of stage travel.
2 Orthogonality of Height and Width (H & W) apertures.
3 Parallelism of Height and Width (H & W) aperture edges.
4 Alignment Height and Width (H & W) apertures with stage motions.
5 ±X, ±Y stage setting precision.
6 Zero-degree repeatability of aperture rotation motion.
7 45-degree accuracy of Height and Width (H & W) apertures.
8 Size and alignment precision of Height and Width (H & W) motions.
9 Focus.
10 Reduction lens distortion (if present).
11 Uniformity of exposure density.
12 Stability and straightness of X and Y stage motions.
13 Angle setting accuracy using ± angles.
14 Concentricity of center of aperture and center of aperture rotation.
15 Loop closing ability of X and Y stage motions and variable apertures.

The entire angle and alignment accuracy test can be generated on a photographic plate measuring 2 in. x 2 in. square, or larger. Plate 4 is approximately a 5X magnification of an angle and alignment test plate made on a Pattern Generator using data inputs identical to that furnished with each instrument. Much of the fine detail on Plate 4 can only be seen with the aid of a low power magnifier. A numbered transparent overlay sheet is used in conjunction with Plate 4 to identify a specific area or item being described in the text. The sequence of image generation is identified on Plate 4 by the following numbers:

1 X, Y origin and directional reference marks.
2 X coordinate scale. Spacing is 5.0 mm.
3 Three parallel lines of differing thickness generated in X coordinate direction by butting segments using a small height (H)/large width (W) aperture.
4 Small width (W) line generated in Y coordinate direction by butting segments using a small width (W)/large height (H) aperture.
5 Large width (W) line generated in Y coordinate direction by butting segments using a large height and width (H, W) aperture.
6 Large height (H) line generated in X coordinate direction by butting segments using large height and width (H, W) aperture.
7 One of three segments of a vertical grating generated using a large height (H)/small width (W) aperture. Made prior to aperture rotation tests. Remaining segments are 15 and 16.
8 One of two segments of a horizontal grating generated using a small height (H)/large width (W) aperture. Made prior to aperture rotation tests. Remaining segment is 18.

9 Vertical grating generated consecutively by butting three segments obtained using a large height (H)/small width (W) aperture. Made prior to aperture rotation tests.
10 Vertical grating generated consecutively by butting three segments obtained using a large height (H)/small width (W) aperture. Made prior to aperture rotation tests.
11 Vertical grating generated consecutively by butting three segments obtained using a large height (H)/small width (W) aperture. Made prior to aperture rotation tests.

12 Horizontal grating generated consecutively by butting two segments obtained using a small height (H)/large width (W) aperture. Made prior to aperture rotation tests.
13 Horizontal grating generated consecutively by butting two segments obtained using a small height (H)/large width (W) aperture. Made prior to aperture rotation tests.

14 A rosette generated in two parts using increasing angle (+A) setting only. First part utilizes small height (H)/large width (W) aperture with consecutive exposures from 0 through 85 degrees in 5 increments. The second part is identical except a large height (H)/small width (W) aperture is employed.

15 Remaining two segments of vertical grating generated consecutively by butting a small width (W)/large height (H) aperture against a single segment (7) made prior to generation of the increasing angle (+A) rosette.
16 Remaining two segments of vertical grating generated consecutively by butting a small width (W)/large height (H) aperture against a single segment (7) made prior to generation of the increasing angle (+A) rosette.

17 A rosette generated in two parts using decreasing angle (-A) settings only. First part utilizes a small height (H)/large width (W) aperture with consecutive exposures from 85 through 0 in 5 degree increments. The second part is identical except a large height (H)/small width (W) aperture is employed.
18 Remaining second segment of vertical grating generated using small height (H)/large width (W) aperture.

19 Three sizes of dots generated in two parts using increasing angle (+A) settings only. Quadrants two and four utilize a small height (H)/large width (W) aperture with consecutive exposures 0 through 88 in 2 degree increments. The second part is identical except a large height (H)/small width (W) aperture is used to generate quadrants one and three. In each instance the small dimension is selected so that corners of adjacent exposures forming the dot will butt at the circumference.
20 Three sizes of dots generated in two parts using increasing angle (+A) settings only. Quadrants two and four utilize a small height (H)/large width (W) aperture with consecutive exposures 0 through 88 in 2 degree increments. The second part is identical except a large height (H)/small width (W) aperture is used to generate quadrants one and three. In each instance the small dimension is selected so that corners of adjacent exposures forming the dot will butt at the circumference.

21 Three sizes of dots generated in two parts using increasing angle (+A) settings only. Quadrants two and four utilize a small height (H)/large width (W) aperture with consecutive exposures 0 through 88 in 2 degree increments. The second part is identical except a large height (H)/small width (W) aperture is used to generate quadrants one and three. In each instance the small dimension is selected so that corners of adjacent exposures forming the dot will butt at the circumference.

22 A 0 and 89 degree aperture rotation check obtained by generating dual crosses.

23 A 45-degree latticework generated by fixing the aperture assembly at +45 degrees and alternately making exposures with a small height (H)/large width (W) aperture, then with a large height (H)/small width aperture. Spacing for each row of latticework exposures is obtained using X coordinate stage motion.

24 Y coordinate scale. Spacing between exposures is 5.0 mm.

6. 3. 1 Analysis of Angle and Alignment Accuracy Test

Suggested procedures for analyzing the angle and alignment accuracy test to evaluate the fifteen system functions listed in Section 6.3 are described in the following paragraphs. Illustrations for evaluating individual angle and alignment tests can be found in Section 6. 4. These illustrations are identified as Plate 1 through Plate 6. Analysis of the fifteen system functions will follow the same order as initially listed at the beginning of Section 6. 3.

(1) **X and Y Stage Motion Accuracy**
The X and Y coordinate scales (Plate 4, Items 2 and 24) are made using a spacing of 5. 0 mm in both coordinates. Accuracy of the X, Y coordinate stage motions can be determined by measuring the distance between any two lines on a suitable measuring device. When checking accuracy, be sure to compensate for errors in the measuring instrument and for temperature differences. The Pattern Generator is calibrated to be accurate at 20 deg. Celsius (68 deg. Fahrenheit).

(2) **Orthogonality of Height and Width (H & W) Apertures**
The small height and width gratings (Plate 4, Items 8, 12 and 7, 9) are used to check orthogonality of the variable aperture motions. The gratings are generated using butted segments. Lines in all segments are located on 20µ center distances and measure 10µ x l000µ. The vertical gratings (Plate 4, Items 9, 10, 11 and 7, 15, 16) consist of three butted segments. To determine orthogonality of the variable apertures, observe the joints where the segments are butted to form long lines. If all butted joints are aligned so the image appears as one long line (illustrated on Plate 5, Part A), the variable aperture height and width motions are orthogonal. The aperture motions are also orthogonal if the butted joints are not aligned but similar. Plate 5, Part B shows an example of apertures that are orthogonal but not parallel to the X and Y coordinate motions of the instrument. Plate 5, Part C is an example of the aperture height motion not being at right angles to the width motion.

(3) **Parallelism of H & W Aperture Edges**
The horizontal and vertical gratings (Plate 4, Items 8 and 16) are also used to determine if opposite sides of the variable aperture are parallel to each other. When opposing sides are parallel to each other they will appear as shown on Plate 5, Part A. If opposing sides are not parallels long narrow apertures will have taper that can easily be seen at butted joints, as illustrated on Plate 5, Part D.

(4) **Alignment of H & W Apertures with Stage Motions**
Alignment of the aperture height and width with respect to the X and Y coordinate stage motions can be evaluated by using the horizontal and vertical gratings (Plate 4, Items 13 and 9) and the long segmented height and width lines (Plate 4, Items 3 and 4). If the butt joints between grating segments appear as illustrated on Plate 5, Part A, the aperture motions are parallel to the X and Y coordinate motions. Plate 5, Part B also shows an example of orthogonal and parallel aperture height and width openings; however, the illustration additionally shows that the aperture motions are not parallel to the X and Y coordinate stage motions due to an aperture angle setting error at the zero-degree position.

(5) **±X, ±Y Stage Setting Precision**
The stage setting precision can be determined by examining the horizontal and vertical gratings (Plate 4, Items 13 and 18). Each of the lines in these gratings is created by butting 10µ x 1000µ segments. A new stage setting is required for each segment; therefore, similarity of butt joints between segments is dependent upon precision of the stage motions.

(6) **Zero Degree Repeatability of Aperture Rotation**
The order in which the two sets of horizontal and vertical gratings are generated is used to determine how well the aperture assembly will return to its original position after extensive rotation within the 0 degree to 85 degree range of angular motion. The lowest segment (Plate 4, Item 7) in the right-hand vertical grating, the right-hand segment (Plate 4, Item 8) in the right-hand horizontal grating and all segments in the left-hand vertical grating (Plate 4, Items 9, 10, 11) and horizontal grating (Plate 4, Items 12, 13) are made prior to any rotation of the aperture assembly. After the plus angle (+A) rosette (Plate 4, Item 14) is created, the remaining two segments of the right-hand vertical grating (Plate 4, Items 15, 16) are completed. After the (-A) rosette (Plate 4, Item 17) is created, the remaining segment of the horizontal grating (Plate 4, Item 18) is made. The butt joints between the bars in each segment should be similar in appearance. Any lack of similarity between those butt joints made before and after generation of the rosettes is caused by failure of the aperture assembly to return to zero degrees.

(7) **45 Degree Accuracy of H & W Apertures**

A latticework (Plate 4, Item 23) test is generated with the aperture assembly rotated to a +45 degree angle. The accuracy of the +45 degree angle setting can be determined by observing the butt joints within the pattern. The joints should appear as shown in Plate 5, Part E. Part F is an example of angle setting error, and shows rotation in excess of 45 degrees.

(8) **Size and Alignment Precision of H & W Motions**

The 45 degree latticework (Plate 4, Item 23) test is also used to check the precision of the aperture sizes and height and width guidance motions. The height and width aperture sizes alternately change for each successive exposure. All latticework exposures are made with a fixed aperture rotation angle of +45 degrees. The left-hand side of the lattice tests for aperture width size and angle precision. The right hand side tests for aperture height and angle precision. The similarity of the butt joints within the latticework is, therefore, dependent on the size and angle alignment precision of the aperture assembly drive motions.

(9) **Focus**

For this test it is extremely important that the glass plate used be flat to a tolerance of 0. 0025 mm (0. 0001 in.) TIR, or better. To determine if good focus is being maintained, inspect the quality of images made at different locations on the test plate. Image quality should be uniform for all exposures. A variation in image quality indicates a focus problem which can be caused by any of the following conditions.

a Test plate not flat.
b Locating pads in plateholder are dirty.
c Surface of stage to which plateholder is clamped is dirty.
d Plateholder clamping surface is burred, or bent.
e The vacuum may be insufficient to hold the plate firmly against the locating pads in the plateholder.

(10) **Reduction Lens Distortion**

A series of 1000µ (1. 0 mm) square exposures are butted in both the X and Y coordinates to form continuous wide lines (Plate 4, Items 5 and 6). The butt joints in these lines are utilized to detect reduction lens distortion. If there is no distortion in the reduction lens, the butt joints in both the X and Y coordinate lines should appear similar to those illustrated on Plate 6, Part A. A lens with barrel distortion would produce an image similar to that shown on Plate 6, Part B.

(11) Uniformity of Exposure Density

The wide continuous X and Y lines (Plate 4, Items 5 and 6) are made by butting large square images together. Any single frame composing these lines can be used to gauge the uniformity of exposure. All frames should appear similar and be uniform in density over the exposed area to ± 0. 2 density units at density 2. 0 when measured with a densitometer.

(12) Stability and Straightness of X and Y Stage Motions

The stability and straightness of the X and Y co ordinate stage motions is determined by examining the small height lines (Plate 4, Item 3) and small width line (Plate 4, Item 4). The butt joints between the segments which make up these lines should all be similar in appearance. Any variation is caused by a lack of straightness and/or stability in the stage motions.

(13) Angle Setting Accuracy Using ± Angles

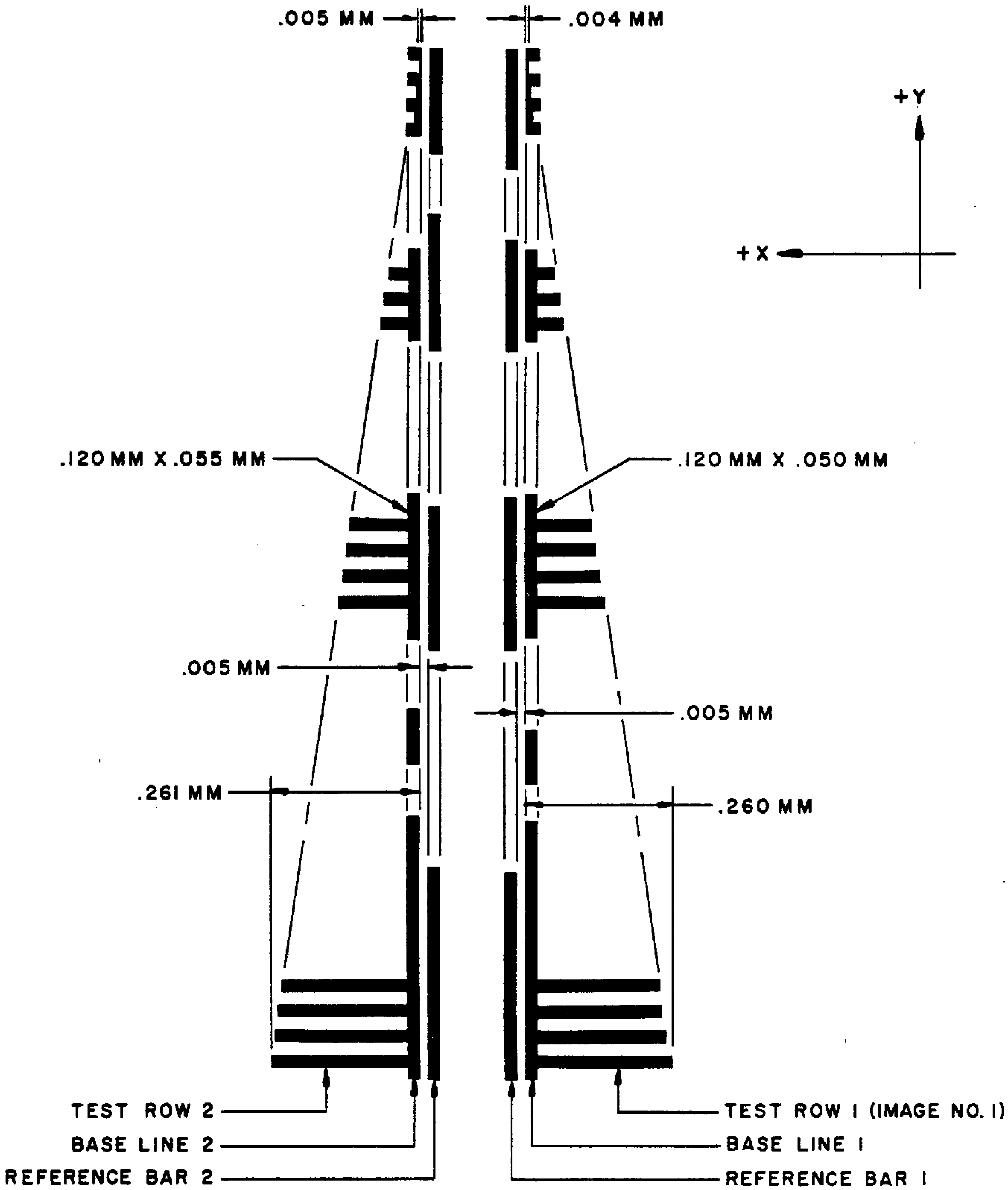
The three solid circles (Plate 4, Items 19, 20, 21) are used to check ± angle accuracy of the variable aperture assembly. Each circle is composed of ninety (90) long thin rectangles exposed at 2 degree intervals. The diameters of the circles are 1000µ, 750µ, and 500µ. Opposite quadrants of the circles should appear similar. Quadrants one and three are generated with forty-five (45) bars having a large height dimension and a small width dimension. In quadrants two and four the height and width dimensions are interchanged to provide forty-five bars having a small height and a large width dimension. In a 400X laboratory microscope the central portion of each circle is very dense due to the multiple exposures. Where the long, thin rectangles overlap, rays appear to radiate from the center of each circle. At the circumference there may appear to be very minute notches where the corners of successive exposures meet. These notches are related to the discrete stepping increments inherent to the test design. Plate 6, Part C represents a sketch of a portion of a solid circle as viewed with a 400X laboratory microscope. Angle stepping error will cause a variation in the length of the rays within each quadrant, as well a variation in the size of the notches at the circumference. In all quadrants the rays and notches (if visible) should be of uniform size and quality.

(14) Concentricity of Center of Aperture and Center of Aperture Rotation

If the center of the aperture formed by the aperture height and width motions is not coincident with the mechanical axis around which the variable aperture assembly rotates, it can be detected by examining the circles (Plate 4, Items 19, 20, 21) and feathered cross (Plate 4, Item 22) and the two rosettes (Plate 4, Items 14, 17). The perimeter of the double exposed area of the rosettes should appear circular about the center of the rosette and symmetrical in opposite quadrants. The feathered cross is made up of two crosses, the second of which is formed after the variable aperture assembly is rotated 89 degrees. The position of the X, Y coordinate stages is the same for both exposures. The double exposed areas of the feathered cross should be symmetrical about a common center.

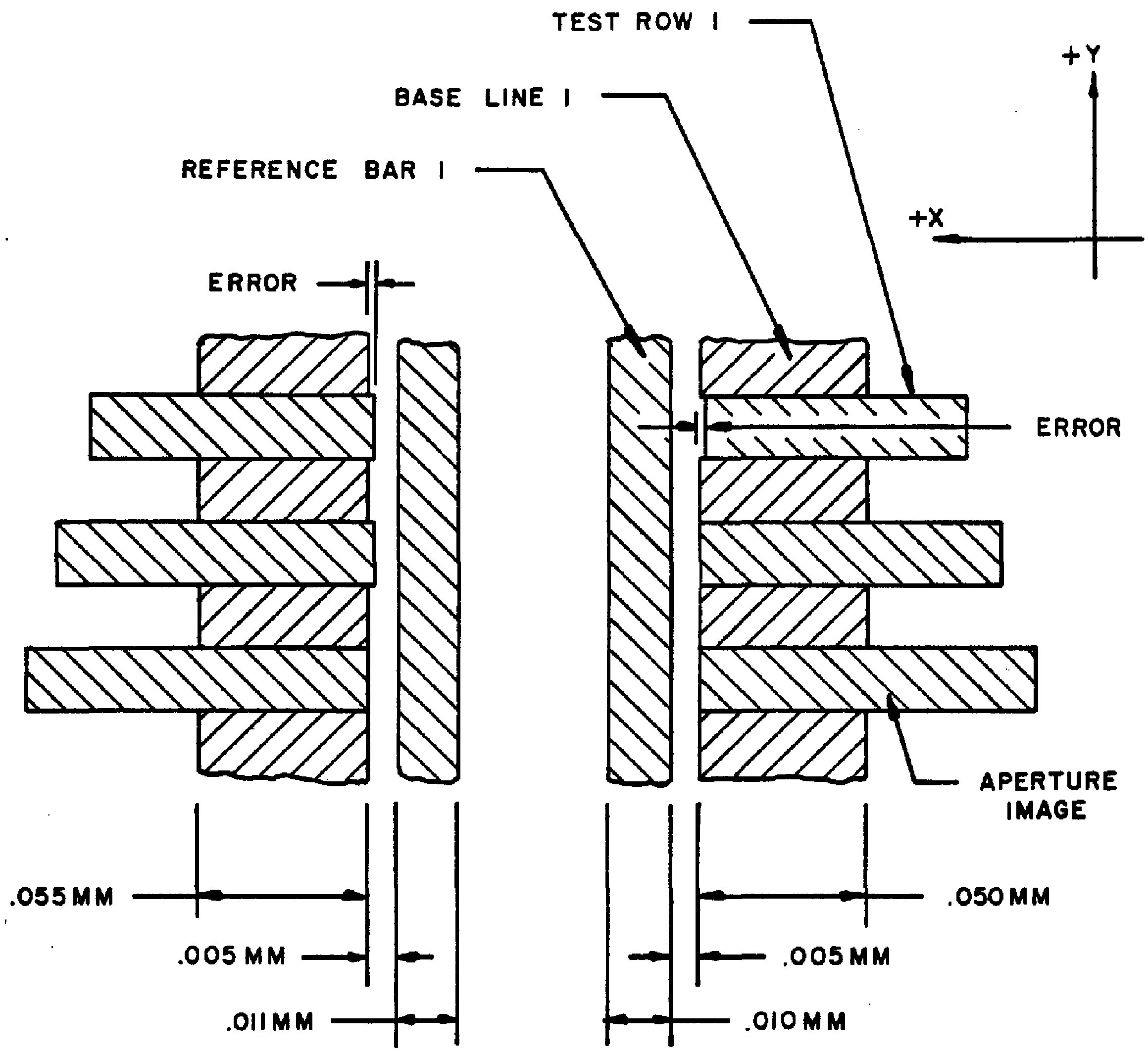
(15) **Loop Closing Ability of X and Y Stage Motions, and Variable Apertures**
The butt joint (Plate 4, Item 24) is utilized to determine the loop closing ability of the Pattern Generator. The segment at the origin end of the middle X coordinate line (Plate 4, Item 3)is created near the beginning of the test. The lowest segment of the Y coordinate scale (Plate 4, Item 24) is the last exposure and has the same size as the first segment. These two exposures (widely separated in time) are made with a common Y coordinate stage setting. The X coordinate stage settings differ by 1000 so the ends of the two exposures will butt. The butt joint between these two segments will be of the same quality as the other joints in the long X coordinate lines (Plate 4, Item 3) when the loop is successfully closed.

6.4 Plates



SMALL HERRINGBONE WIDTH TEST FOR APERTURE SIZES
FROM: .004 MM TO .261 MM IN .001 MM INCREMENTS

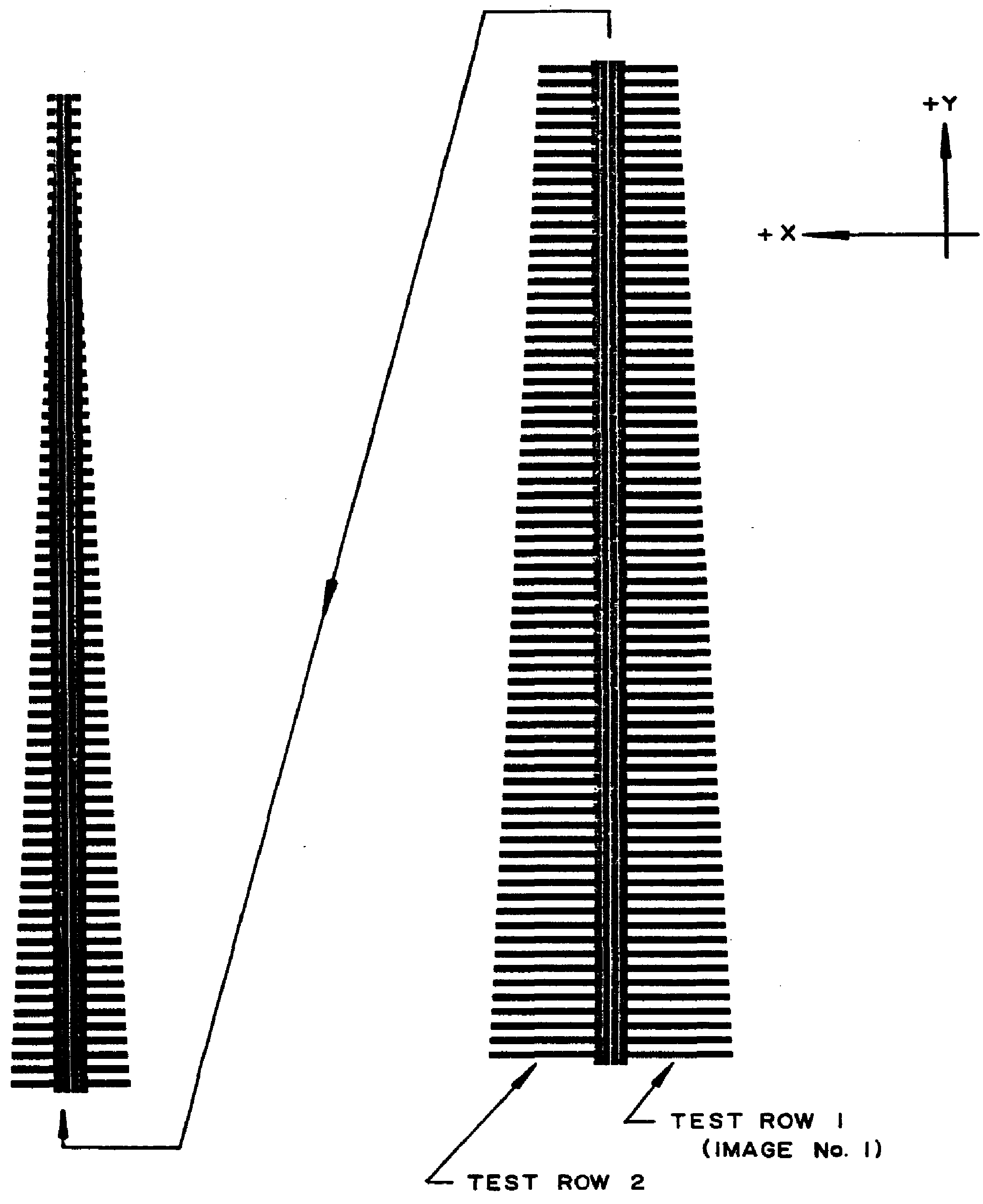
PLATE 1



PORTION OF HERRINGBONE TEST ENLARGED TO SHOW ERRORS
.001 MM APERTURE INCREMENTS.

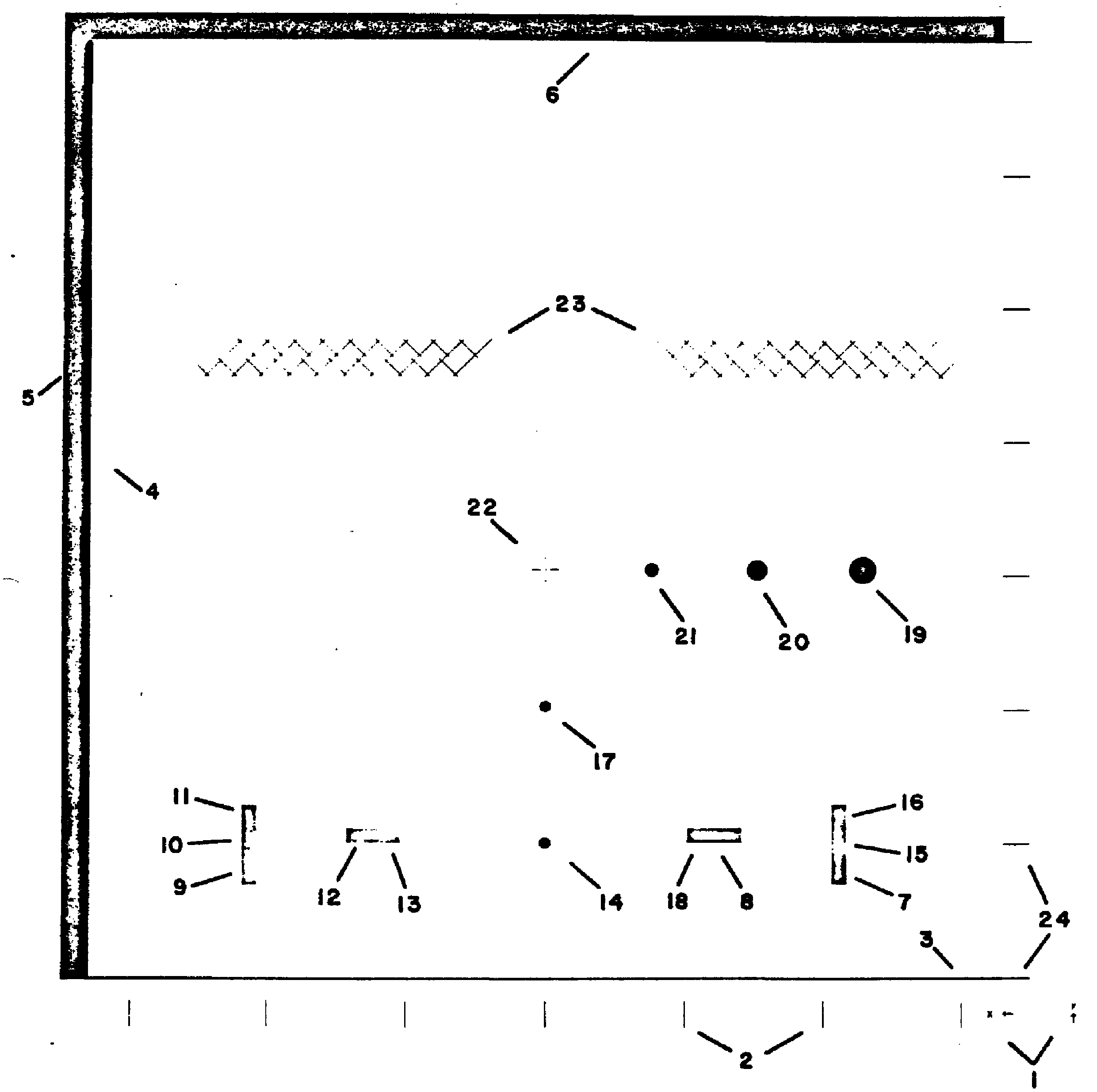
NOTE:
DIMENSIONS APPLY TO SMALL HERRINGBONE TEST FOR APERTURE SIZES FROM .004MM TO .261MM ONLY.

PLATE 2



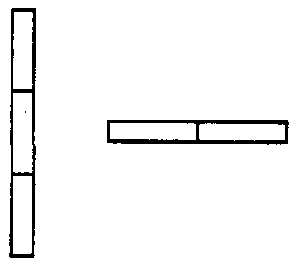
LARGE WIDTH HERRINGBONE TEST FOR APERTURE SIZES
.005 MM TO 1.0 MM IN .005MM INCREMENTS

PLATE 3

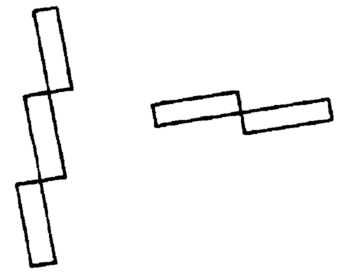


APERTURE ANGLE AND ALIGNMENT ACCURACY TEST

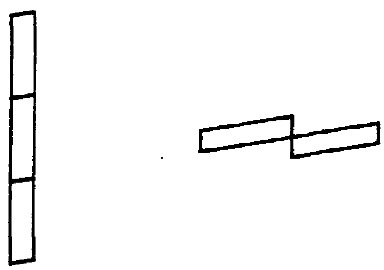
PLATE 4



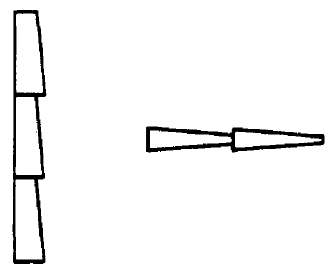
PART A



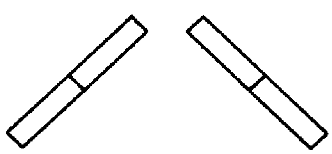
PART B



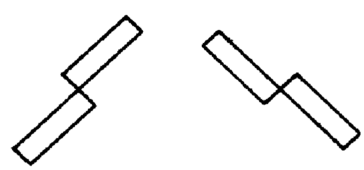
PART C



PART D

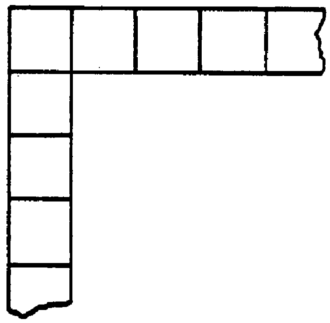


PART E

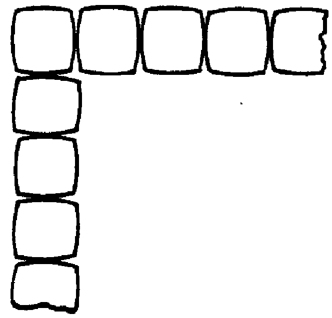


PART F

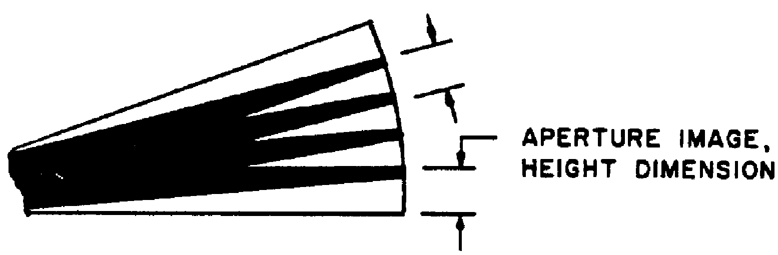
APERTURE ANGLE AND ALIGNMENT ACCURACY TEST



PART A



PART B



PART C

APERTURE ANGLE AND ALIGNMENT ACCURACY TEST

PLATE 6