

Jan. 6, 1959

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2,867,149

METHOD OF DETERMINING SURFACE FLATNESS

Filed Oct. 5, 1953

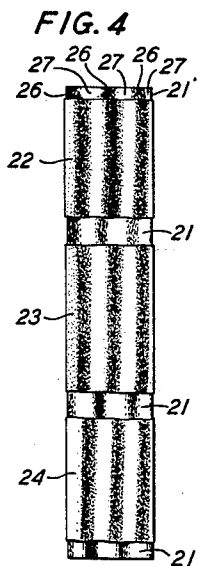
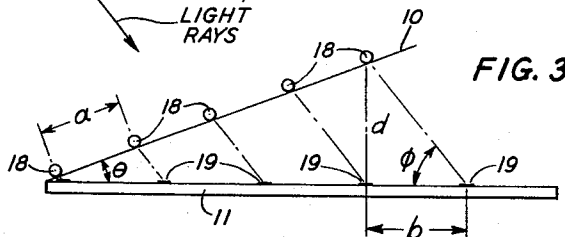
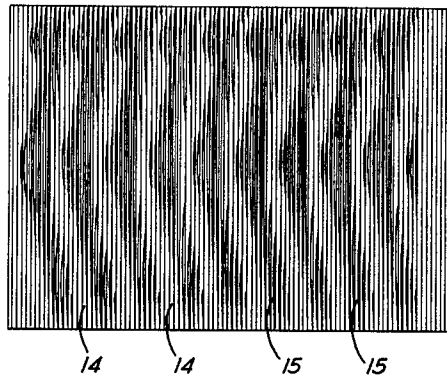
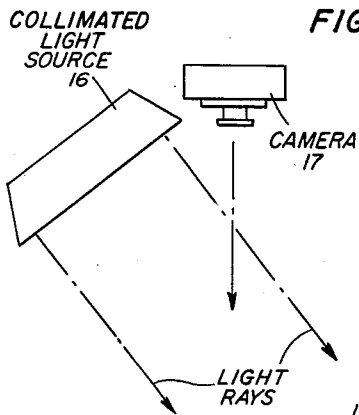
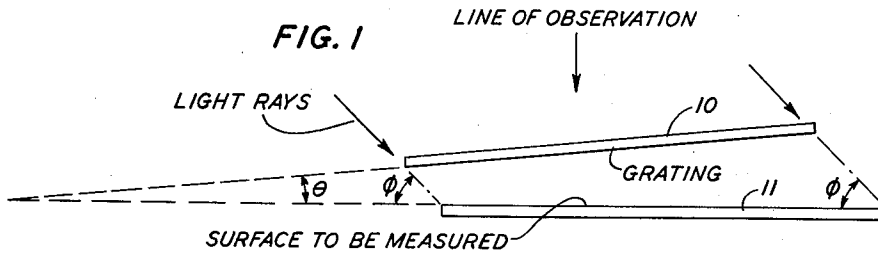


FIG. 6



FIG. 7



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METHOD OF DETERMINING SURFACE
FLATNESS

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Application October 5, 1953, Serial No. 384,144

4 Claims. (Cl. 88—14)

This invention relates to methods of determining surface flatness and more particularly to such methods applicable to the measurement of the flatness of coated cathode surfaces.

The pursuit of improved designs of broadband grid control electron tubes for use in video or I. F. amplifiers has led to closer and closer spacing between cathode and control grid. Circuit degradation of gain-band product resulting from stray wiring capacitance suggests the use of relatively large cathode areas for improved performance. As a result of these two factors there are several tubes now in manufacture in which the ratio of cathode length to grid-cathode spacing is approximately 300:1. In tubes now under development the ratio is 700:1.

If it is desired to hold a production quality range of the order of ± 20 percent in important electrical characteristics, it is found that the average spacing between control grid and cathode must be held to approximately ± 10 percent. In attaining this average spacing range, it is found that the order of an additional ± 10 percent in tilt, sag, waviness or twist in the cathode or grid plane is permissible. The ratio of cathode length to permissible departure from surface flatness is thus 7,000:1. This is roughly equivalent to requiring that a football field be graded flat to within one-half an inch. For an electron tube cathode the problem is more severe since the flatness requirement must be held for thousands of hours of operation at the order of 1000 degrees Kelvin.

It is therefore desirable in the manufacture of tubes to be able to measure this degree of surface flatness. Measurement by optical flats is not feasible because of the granular texture of the carbonate coated surface. Measurement by conventional mechanical probing of the profile would damage the carbonate coating and be time consuming for uncoated cathodes.

It is a general object of this invention to provide a method of determining surface flatness and more particularly to provide such a method applicable to the measurement of the flatness of coated cathode surfaces.

More specifically among the objects of this invention are to enable the rapid and facile checking of cathodes for surface irregularities prior to their incorporation into vacuum tubes and to enable a quantitative determination of the departure of a surface from a priorly chosen plane.

In accordance with one specific embodiment of this invention, a grating of fine wires or ruled lines is positioned at an angle to the surface being measured and a source of parallel rays of light positioned so as to project the light through the grating at any angle to the surface. Because of the angles of the light and of the grating with respect to the surface, the distance between successive shadows of the grating wires or lines on the surface is different from the apparent distance between the wires of the grating themselves when viewed from directly above the surface. This gives rise to alternate bands of dark and light regions, as explained further below.

If the surface is perfectly flat these bands will be

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straight. If the surface is stepped, the bands will appear to have discontinuities in them and themselves appear stepped. If the surface has depressions in it, the bands will be bowed. The dark bands will in effect provide a linearly magnified picture of the cross section of the surface being measured.

If the angle between the grating and the surface is small and the light is incident on the surface at 45 degrees, the deviation or distortion of the dark bands from being straight bands, expressed as a ratio, times the distance between adjacent wires or lines on the grating is the quantitative amount of the distortion or departure from flatness of the cathode surface. This departure may be a depression, caused during the manufacture of the cathode which has to be observed to prevent the incorporation of this cathode into a tube having close spacing between cathode and grid, or this departure may be due to a coating on the cathode, the technique of this invention thus giving a quantitative determination of coating thickness.

The determination of the ratio of dark band distortion to the distance between dark band centers may be made by adjusting the angle of the grating to the surface to any convenient small value, by using measuring rulers or guides, or by employing a grating having a varying spacing of lines or wires and through which the observation of the pattern is made.

It is therefore a feature of this invention that a determination of surface flatness be made by positioning a grating at an angle to the surface being tested, projecting parallel rays of light through the grating onto the surface so as to be incident to the surface at an acute angle, and observing the resulting pattern of alternate dark and light bands from a position directly above the surface.

It is a further feature of this invention that the light be incident on the surface at an angle of 45 degrees and that the grating be at a small angle to the surface so that the ratio of deviation of a dark band from a straight line to the distance between dark bands times the actual distance between the wires or lines of the grating is a quantitative determination of the deviation of the surface from flatness.

A complete understanding of this invention and of these and various other desirable features may be gained from consideration of the following detailed description and the accompanying drawing, in which:

Fig. 1 is a diagrammatic representation of the apparatus employed in the practice of this invention;

Fig. 2 is an idealized illustration of one pattern of alternate bands of dark and light regions observed during the practice of this invention;

Fig. 3 is an idealized diagrammatic representation of the apparatus of this invention utilized in the description in the proof of certain geometric relationships advantageously employed in the practice of this invention; and

Figs. 4 through 7 are actual pictures of various patterns of the dark and light bands observed during the practice of this invention.

Turning now to the drawing, Fig. 1 illustrates the apparatus employed in this novel method. A grating 10, which may be a fine wire type of grid or may consist of opaque lines ruled on a flat glass sheet, is mounted at an angle θ with respect to the test surface 11. A grating having 300 to 1000 lines per inch is convenient for determining departure from flatness of the order of 0.0003 to 0.0001 inch. The incident light, which is presumed from a source sufficiently distant so that the light rays are parallel, describes an angle ϕ with respect to the test surface 11. The direction or line of observation is as shown and is perpendicular to the test surface 11. This observation may be visual or photographic. Each line of

the grating 10 will cast a distinct shadow on the test surface 11 and the angular position of the light source will cause the observed distance between lines or wires of the grating to be different from the observed distance between the shadows cast by these lines on the test surface. As these distances are different there will be regions where the shadows appear to lie between the lines of the grating and other regions where the shadows will be behind lines of the grating. These regions can be seen in Fig. 2 where both the grating lines and shadows are clearly described. Ignoring, for the moment, the curvature of the regions, we can determine that there are successive regions 14 in which the grating lines and the shadows nearly coincide and other regions 15 in which the lines and shadows are interlaced. The regions 14 will appear light or gray while the regions 15 will appear dark or black. Actually, as seen in Figs. 4 through 7, the grating lines and shadows are not individually visible, but they have been depicted in Fig. 2 for purpose of explanation.

The reason for the appearances of these two distinct regions and their employment in measuring techniques and methods in accordance with my invention can be best understood from a consideration of Fig. 3 which is an idealized diagram of a grating 10 having n wires 18 of which the first wire is in contact with the surface 11 being tested. As in Fig. 1, the grating 10 makes an angle θ with the test surface 11 and the light rays are at an angle ϕ to the test surface 11. In Fig. 3 there are also depicted a collimated light source 16 of parallel light rays and a camera 17 which may be used to photograph the band patterns such as are depicted in Figs. 4 through 7.

Each of the n wires will cast a shadow 19 on the flat surface and we assume that the shadow 19 of the $(n-1)$ th wire 18 appears in the line of observation to be directly under the n th wire 18. The distance between the wires 18 is a and the distance between the shadows 19 is b . Because of the angle ϕ of the light rays the distance b will be greater than a and further because of the angle θ at which the grating 10 is inclined to the surface 11 the distance a will appear to the line of observation to be smaller than it actually is.

Let us now solve for the distance d between the n th wire and the surface 11 in terms of the various parameters of this geometrical system. As we have assumed that the shadow 19 of the $(n-1)$ th wire 18 is directly under the n th wire 18, a right triangle is formed having as sides d , na and $(n-1)b$ and in which

$$na \cos \theta = (n-1)b \quad (1)$$

A second right triangle is also formed in which

$$d = b \tan \phi \quad (2)$$

If we substitute for b in Equation 2 the expression for b determined by Equation 1 then

$$d = \frac{n}{n-1} a \cos \theta \tan \phi \quad (3)$$

By choosing the angle ϕ at which the light rays impinge on the surface 11 to be 45 degrees and the angle θ to be a small angle, then if n is not a small number,

$$\frac{n}{n-1} \approx 1$$

$$\cos \theta \approx 1$$

$$\tan \phi \approx 1$$

and

$$d \approx a \quad (4)$$

n is the number of wires 18 until the shadow of the $(n-1)$ th wire is approximately directly beneath a wire and in actuality is of the order of magnitude of 20 to 30 or larger for such values of the angle θ so that the above assumption is valid. It should also be pointed out that the two assumptions with respect to n and θ are of opposite sign and therefore tend to correct each other.

Equation 4 states that the distance of the wire 18 under which the shadow 19 of a preceding wire exists is approximately the distance between the wires 18 of the grating 10. If we turn again to Fig. 2 the occurrence of the shadow of a prior wire under another wire gives rise to the light regions 14 while the occurrence of the shadow 19 between the wires 18, as seen in the line of observation, gives rise to the dark regions 15.

While the proof of Equation 4 has assumed, as seen in Fig. 3, that the first wire 18 be contiguous to the surface 11 and that the shadow under the n th wire be that of the $(n-1)$ th wire, this proof can be generalized as the shadow under the $2n$ th wire will be from the $2(n-1)$ th wire, etc., and in each case the distance from the wire to the surface will be an integral multiple of the spacing a between the wires 18 of the grating 10. As the distance between all the light regions 14, or conversely the centers of the dark regions 15, is now determined in terms of the known spacing of the wires of the grating 10, the application of this valuable expression, Equation 4, to surface flatness measurements can be readily explained.

Fig. 4 depicts the observed patterns of dark and light regions for a particular cathode surface especially coated to illustrate certain facets of this invention. In Fig. 4 the cathode has four uncoated areas 21 and three coated areas 22, 23 and 24 the thickness of which coatings are different. The grating is tilted so as to be closest to the cathode surface at the left edge of the cathode. At the top edge of the cathode in the first uncoated region 21 are seen three dark bands 26 and three light bands 27. The grating employed had 400 lines to the inch so that the spacing a between adjacent lines was 0.0025 inch.

As can be seen in Fig. 4, the dark bands 26 over coating 22 are not in line with the dark bands 26 at the uncoated portion 21. If we measure from the center of one dark band 26 on portion 21 to the center of the same dark band 26 at coating 22 we find that the distance is about two-tenths the distance between the centers of adjacent dark bands on the uncoated portion 21. As we know that the distance from the grating to the surface is an integral multiple of the distance a between adjacent wires or lines of the grating, we can calculate that the height of the coating is two-tenths of the distance between adjacent wires of the grating or 0.0005 inch. Because of the direction of the deviation of the regions over the coated portion we know that the deviation is caused by an increase, rather than a decrease, in the surface position. Similarly we can determine that the thicknesses of the coatings 23 and 24 are approximately 1 and 2 mils, respectively. If the thickness of the last coating had been exactly 2.5 mils, the dark regions would have been aligned with the dark regions on the uncoated portion but, as can be seen in the drawing, there are dark transition lines along the line separating the uncoated and coated portions which connect the two parts of the same dark region together and which would advise us of the true state of facts.

Fig. 4 illustrates the application of this technique to recognizing steps in otherwise perfectly flat surfaces and to determining the amount of the step. Figs. 2 and 5 illustrate the application of this technique in determining the presence of slight and gradual cavities in the surface. As can be seen in Fig. 5 the dark bands 30 tend to bow to the left in the middle. This indicates a slight depression in the cathode surface, the depression being deepest in the center of the cathode and extending out towards both ends. By measuring the deviation of the center of the dark band at the center of the cathode from the position of the center of the dark band if it had been straight, the actual depth of the depression can be determined. In this case, again employing a grating having 400 wires to the inch, the deviation was four-tenths of the total distance so the depression was four-tenths of 0.0025 inch or 0.0010 inch.

In the commercial checking of cathode surfaces, the

cathodes are individually observed by a worker who may advantageously be provided with a ruled gauge or a grating in which the number of lines per inch varied along the grating. He would then determine the reading on the gauge or this special grating for the point of maximum bowing. If it indicated a departure of more than a certain percentage from the distance between dark bands on a perfectly flat surface, the cathode would be rejected. Such a procedure can readily be mechanized and may be accomplished by unskilled workers.

Fig. 6 shows the pattern observed on a cathode having both a depression extending from its center to the two edges and also wrinkles or slight ruts on the surface. Such a cathode would be quickly discarded during the checking process purely on a visual observation without any measurement of the depth of the depressions. The peculiar appearance of the dark bands at the very edges of the cathode indicates that this cathode had sloping sides which did not drop off very rapidly. It is apparent that by employing this technique one can obtain a very accurate picture of the appearance of the surface of the cathode. Thus the outline of the dark bands in Fig. 6 are an indication, greatly magnified, of the outline of the cathode surface itself. It should be emphasized, however, that while the outline of the dark bands shows the surface configuration magnified no optical magnification is employed.

Fig. 7 illustrates a perfectly flat cathode surface. This cathode had been ground flat before the application of the cathode coating.

It is to be understood that the above-described arrangements are illustrative of the application of the principles of the invention. Numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. The method of determining surface flatness comprising positioning a grating having closely spaced parallel lines at an acute angle to the surface whose flatness is to be determined and directly adjacent the surface, projecting parallel rays of light through the grating onto the surface at an acute angle to the surface to form grating line shadows on the surface, and recording through said grating the pattern of superimposed grating line shadows and grating lines to detect deviations from straightness of said grating line shadows, said deviations from straightness corresponding to deviations from flatness of said surface.

2. The method of measuring the thickness of a coating on a flat surface comprising positioning a grating having closely spaced lines at a small acute angle and directly adjacent to the surface having the coating thereon, pro-

jecting parallel rays of light through the grating of an angle of 45° to the surface to the form grating line shadows on said surface, viewing through said grating the pattern of alternate dark and light bands resulting from the superposition of said grating lines and said grating line shadows from a point directly above said surface, and registering the deviation of one said band over the coated portion of said surface from its position over the uncoated portion of said surface relative to the distance between similar points on adjacent similar bands, whereby said deviation indicates the thickness of said coating in terms of the reference fixed by said distance between bands.

3. A method of measuring departures from surface flatness comprising the steps of positioning a grating having closely spaced parallel lines directly adjacent and at a small acute angle to the surface whose flatness is to be measured, projecting parallel rays of light through said grating to form grating line shadows on said surface, viewing through said grating the pattern of alternate dark and light bands resulting from the superposition of said grating lines and said grating line shadows, and registering the deviation from linearity of at least one of said bands over said surface relative to the distance between similar points on adjacent similar bands, whereby said deviation indicates the departure from flatness of said surface in terms of the reference fixed by said distance between bands.

4. The method of producing a pattern of light and dark bands indicative of the deviation from flatness of a surface under inspection comprising positioning a transparent ruled grating in close proximity to said surface and at a small acute angle thereto, directing a collimated light beam at a different acute angle through said grating to project shadows of said grating rulings upon said surface, and photographing the resulting pattern of superimposed rulings and shadows thereof through said grating, whereby said rulings and shadows appear as a pattern of bands, the deviations from straightness of which serve as a measure of the deviations from flatness of said surface.

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