United States Patent [11] 3,628,429

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[21] Appl. No. 881,464
[22] Filed Dec. 2, 1969
[45] Patented Dec. 21, 1971
[73] Assignee U.S. Philips Corporation New York, N.Y.
[32] Priority Dec. 4, 1968
[33] Netherlands
[31] 6817330

[54] EXPOSURE DEVICE FOR MANUFACTURING COLOR PICTURE TUBES

4 Claims, 4 Drawing Figs.

[52] U.S. Cl. 95/1
[51] Int. Cl. G03b
[50] Field of Search 95/1

[56] References Cited

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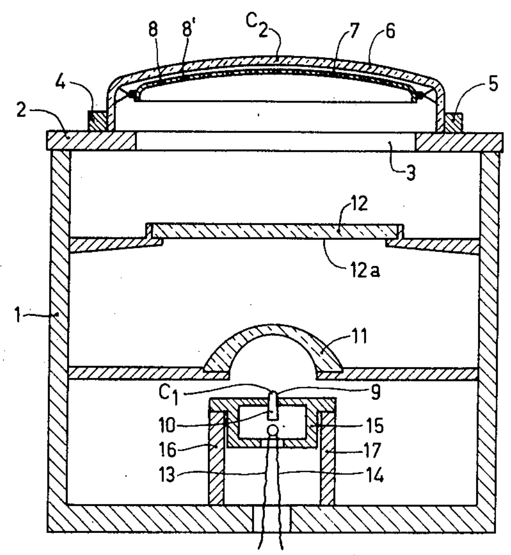
ABSTRACT: An exposure device for projecting aperture patterns from a mask onto a photosensitive layer on a picture screen for cathode-ray tube comprising a conical light source and a substantially rotationally symmetrical negative lens between the light source and the mask to diverge the light thereby enlarging the transverse dimensions of the light source as viewed from the mask. The dimensions of the light source are increased to compensate for any loss in brightness from the lens.



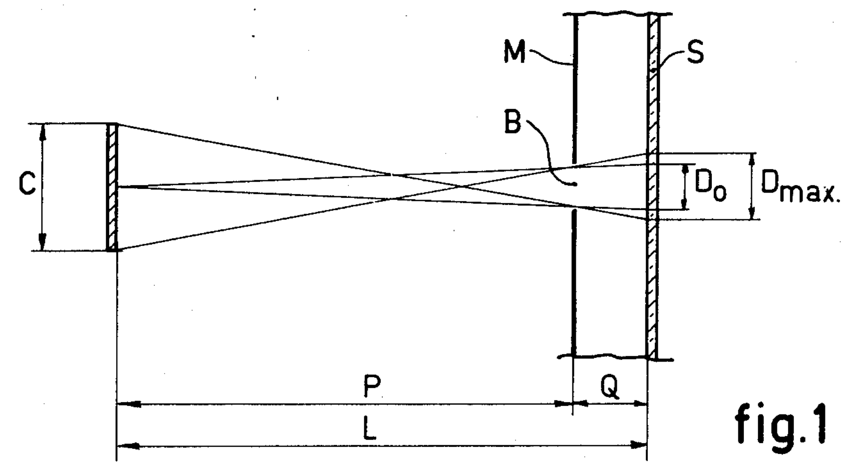


fig.1

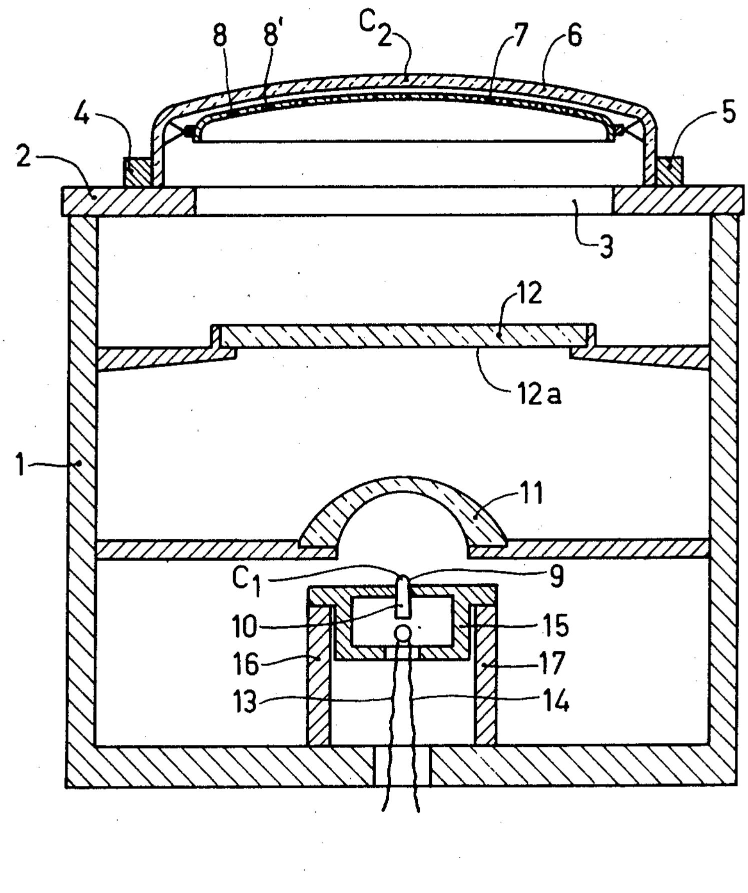


fig. 2

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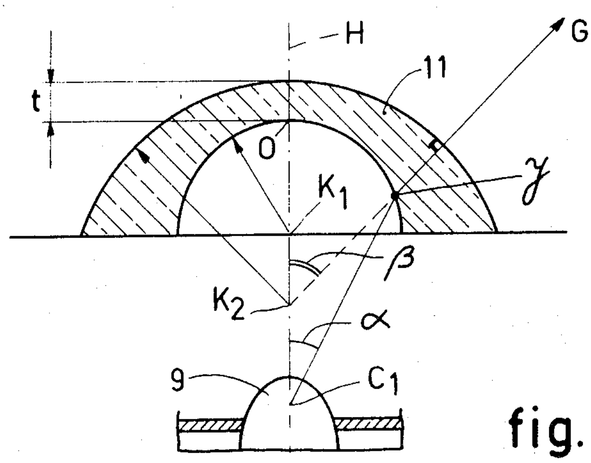

fig. 3

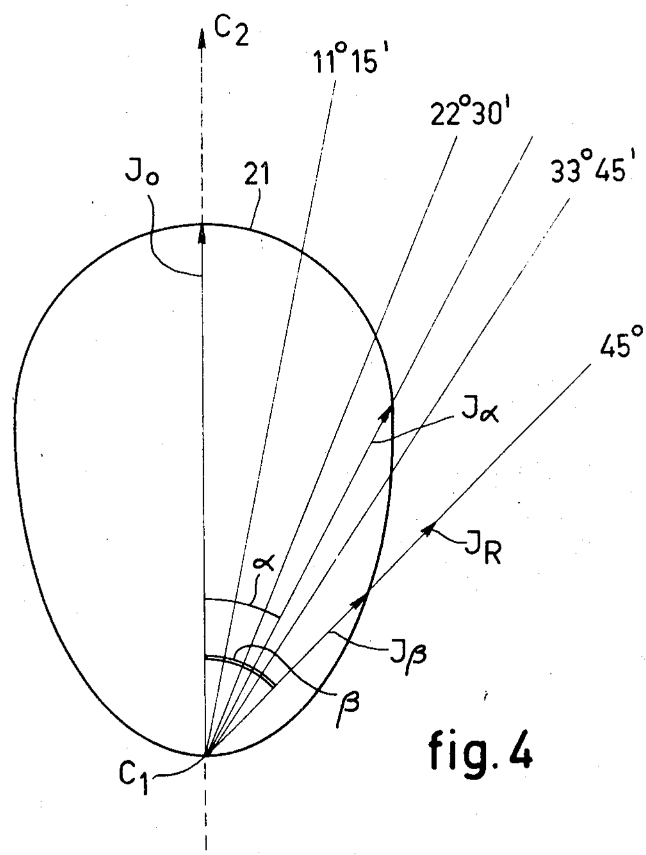

fig. 4

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EXPOSURE DEVICE FOR MANUFACTURING COLOR PICTURE TUBES

The invention relates to an exposure device for manufacturing image screens for cathode-ray tubes for displaying colored images, which device is provided with a light source by which a pattern of apertures in a mask is optically projected onto a photosensitive binder provided on a support, the path of light from the light source to the support passing through a substantially rotation-symmetrical negative lens, the light intensity $I\beta$ from the light source to a point on the edge of the support satisfying the condition:

$$I\beta<\cos\beta/\cos\alpha.I\alpha$$

wherein: β is the angle between the line of connection between the center C_1 of the light source and the center C_2 of the support and the line of connection between C_1 and the point on the edge of the support; and $I\alpha$ is the light intensity of the light source at an angle α with C_1C_2, wherein α is given by the relation:

$$\sin\alpha=(1+v/f)^{-1}\cdot\sin\beta$$

wherein: v is the distance in mm. from the center C_1 to the lens and f is the focal distance in mm. of the lens.

The said support is generally a transparent cover glass which forms part of the future picture screen for the said cathode-ray tube. A support (and a layer possibly provided thereon) of a future picture screen is sometimes also called "-face plate."

The cathode-ray tube mentioned in the preamble is, for example, a color television display tube; it may be, however, alternatively a tube in which colors are made visible on the screen for other purposes.

The light source is, for example, a primary light source having a given light distribution such as a lamp having an internal reflector, or it is a secondary light source. An example of the latter type is weakly matted disc irradiated by a projector. A further example of the latter type is a tip of a conelike light conductor, whereby the lower side of the cone receives light.

A cathode-ray tube for displaying colored images generally includes a system of electrodes which supplies a few electron beams the electrons of which move along different paths through the apertures in a mask towards the screen for generating the so-called primary colors. These are generally the colors green, red and blue. To this end a very large number of "dots" (or stripes) is generally provided in the screen a number of which comprises a luminescent substance which radiates light of one of the primary colors (for example, green) upon electron incidence; other dots on the screen comprise a luminescent substance which radiates light of one of the other primary colors (for example, red) upon electron incidence. A third group of dots may comprise, for example, a blue luminescent substance. However, it is not necessary for the number of different dots and the number of electron beams to be three.

The said screen generally includes a collection of a very large number of "groups" of dots. One group of dots consists of a combination of dots of different composition.

In a known device each electron beam covers (through the mask) only the dots of one and the same composition. By varying the ratio between the intensities of the electron beams different colors can be made visible on the screen.

It is known to provide the said dots on the screen by means of a process in which a layer provided on the faceplate and comprising a luminescent substance and a photoresist is exposed through the mask (color selection mask) by light rays which impinge upon the screen at areas where later the electrons of one of the electron beams will impinge upon the screen. Due to the exposure the luminescent substance is then adhered to the screen at these areas. The substance at the unexposed areas of the screen may be rinsed off. The dots remain. In a following manufacturing stage a layer comprising a different luminescent substance but likewise provided with a photoresist is provided on the faceplate. This new layer is now exposed at such areas that the new "dots" will come at the areas to be impinged upon later by the second electron beam. The latter dots thus are not located at the same areas as the previously provided dots. If necessary this process may be repeated for a third layer, etc. The "exposure" is always effected by means of radiation to which the photosensitive binder reacts. This may be, for example, visible radiation or, for example, ultraviolet light. It is alternatively possible to "expose" a layer which comprises the photosensitive binder only and to provide the luminescent substance only at a later stage.

A known device of the kind described in the preamble is shown, for example, in FIG. 7 of U.S. Pat. specification No. 2,936,682. It is true that the said patent specification gives little information about the light distribution of the tip of the cone 83 but it seems very acceptable that in that case the light intensity will have a greatly decreasing variation in a given direction plotted as a function of the angle which is made by this direction with the line of connection of the tip of the cone and the center of the support 73. This variation will very probably have a greater decrease than is shown by the formula:

$I\gamma=Io\cdot\cos\gamma$, wherein $I\gamma$ is the light intensity in a direction which forms an angle γ with the above-mentioned line of connection and Io is the light intensity in the direction which substantially coincides with the direction of the mentioned line of connection.

If two values for γ namely γ_g and γ_k wherein $\gamma_g>\gamma_k$ are substituted in the formula $I\gamma>Io\cos\gamma$, then it can be derived that $I\gamma_g<\cos\gamma_k/\cos\gamma_g\cdot I\gamma_k$ which is comparable with $I\beta<\cos\beta/\cos\gamma\cdot I\alpha$ so that such a light distribution satisfies the condition mentioned in the preamble.

A different formulation of this condition is that the brightness of a surface element of the light source (that is to say, of an element of the tip of the cone in the case of the patent specification referred to) will be smaller for larger angles with the vertical.

A drawback of the mentioned known device is that additional auxiliary means are usually necessary to maintain the ratio between the illumination value at the area of the center of the support (the screen) and at the area of the edge of the support below an acceptable limit. In general much more light must be radiated towards a spot on the edge of the support than to the center of the support because this edge is farther remote from the light source than the center and furthermore because the apertures of the mask at the area of the edge are more often smaller than those at the center of the support.

A known auxiliary means for obtaining a better illumination distribution on the screen is the use of a filter layer in the light path from the light source to the screen, the permeability of the filter layer being smaller for rays towards the center of the screen than for rays towards the edges. Such a filter causes loss of light which is at the expense of the exposure time.

A further proposed auxiliary means for enhancing the light intensity distribution on the support consists in using a slightly tilted lens between the light source and the support. This, however, has the drawback of an asymmetry in the illumination distribution on the screen.

It is an object of the present invention to obviate or at least mitigate these drawbacks.

An exposure device according to the invention for manufacturing image screens for cathode-ray tubes for displaying colored images, which device is provided with a light source by which a pattern of apertures in a mask is optically projected onto a photosensitive binder provided on a support, and in which the light path from the light source to the support passes through a substantially rotation-symmetrical negative lens and in which the light intensity $I\beta$ from the light source to a point on the edge of the support satisfies the condition:

$$I\beta<\cos\beta/\cos\alpha\cdot I\alpha$$

wherein: β is the angle between the line of connection between the center C_1 of the light source and the center C_2 of the support and the line of connection between C_1 and the point on the edge of the support; and $I\alpha$ is the light intensity of the light source at an angle of α with C_1C_2, wherein α is given by the relation:

$$\sin\alpha=(1+v/f^{-1}\cdot\sin\beta$$

wherein: v is the distance mm. from the center C_1 to the lens; and f is the focal distance in mm. of the lens, is characterized in that the lens satisfies the condition:

$$f<3v.$$

An advantage of this exposure device is that due to the comparatively great divergence of the beam of light from the light source the possibility is created to enlarge the transverse dimensions of the light source. It is true that the spread of the beam of light, which in itself results in an improvement of the center-to-edge ratio of the illumination on the screen, sometimes goes at the expense of the overall quantity of light which is projected onto the screen. However, by simultaneously choosing the transverse dimensions of the light source to be larger, and to at least maintain the brightness thereof, the quantity of light radiated by that source to the screen is increased. This has a compensating effect on the sometimes partially detrimental influence of the above-mentioned divergence. In addition the larger transverse dimension of the light source compensates the reduction of the image from that source which image is obtained with the negative lens. The maximum admissible transverse dimension of the light source is determined inter alia by the properties of the photosensitive layer, the distance between the light source and the screen, the size of the apertures of the mask, etc.

The negative lens in the embodiment of this U.S. patent specification referred to is arranged in such a position and has such a refraction that the reduction of the tip of the cone as viewed from the screen is negligibly small. This lens also serves for completely different purposes.

The reduction factor is smaller than three-fourths in the case of the present invention. This may be explained as follows:

According to the invention there should apply that $f<3v$. The use of formula $M=(1/1+(v/f))$ wherein M is the reduction, yields for $f=3v$: $M=3/4$. For $f<3v$ this formula yields $M<3/4$.

The theoretical background of the invention may be explained as follows:

A prior situation I (prior to the invention) and a novel situation II (subsequent to the invention) are considered.

In situation I a cone tip having a transverse dimension d was used which without the interposition of a (strong) negative lens projected light onto a support provided with a photosensitive binder.

In situation II a cone tip having a transverse dimension D is used which projects light through a negative lens onto a support which is provided with a photosensitive binder.

Apart from a correction factor g the light distribution of the tip of the cone of dimension D is assumed to be the same as that of the tip of the cone of dimension d. Furthermore it is assumed that $D>d$ and $g=(D/d)^2$.

In situation I the light intensity of the tip of the cone into the direction of the center C_2 of the support is given, for example by I_I, and is given by I_{IR} into the direction of the edge of the support.

In situation II the light intensities into these directions (after refraction by the negative lens) are referred to as I_{II} and I_{IIR}, respectively.

The light intensity into a certain direction will now become g times larger due to the use of the larger tip of the cone. However, by interposition of the negative lens each part of the beam of light is deflected and is furthermore diverged over a larger solid angle. If δ_I is the original angle of radiation and δ_{II} is the angle of radiation after deflection, it can be derived that:

$\sin \delta_I=(1+v/f)^{-1} \sin \delta_{II}$ wherein v and f are the object and focal distances, respectively, of the lens.

The divergence in the larger solid angle obtained in situation II implies that the light intensity after refraction by the lens is reduced by a given factor. This factor is:

$$(1+v/f)^{-2}.\cos \delta_{II}/\cos \delta_I.$$

If this is combined with a cone tip which is g times larger, a variation of light intensity in situation II as compared with situation I by a factor of $k=g\cdot(1+v/f)^{-2}\cdot \cos \delta_{II}/\cos \delta_I$ is obtained.

If viewed from the center C_2 of the support the apparent tip of the cone in situation I is equal to that in situation II, then g should be equal to $(1+v/f)^{-2}$. In that case the factor

$$k=\cos \delta_{II}/\cos \delta_I.$$

For a ray from the light source to the center C_2 of the support: $\delta_I=\delta_{II}=0$, thus the factor k is in this case equal to one. In other words in the direction C_2: $I_I=I_{II}$.

For a point of the support the light intensity is I_{IR} and I_{IIR}, respectively. The angle of radiation δ_I is in this case α and $\delta_{II}=\beta$. The factor k thus is $\cos \beta/\cos \alpha$. Hence: $I_{IIR}=\cos \beta/\cos \alpha\cdot I\alpha$.

In a device according to the invention $I\beta<\cos \beta/\cos \alpha\cdot I\alpha$. Hence $I\beta<I_{IIR}$. Or, in other words, the new light intensity I_{IIR} into the direction of a point in the edge of the support is larger than the prior light intensity $I_{IR}(=I\beta)$ to that point on the edge of the support. The light intensities to the center of the support were equal in the situations I and II as was derived above. Hence situation II (that is to say, the situation subsequent to the present invention) with the greater light intensity to the edge of the support provides an advantage relative to situation I. In fact, in this case II the light absorption (in a transmission filter) used for obtaining the correct illumination-distribution on the support can be reduced on its path from C_1 to C_2.

For manufacturing image screens in which the photosensitive binder consists of a photoresist which is soluble in water and which contains a bichromate salt as a sensitizer the dimensions of the light source in mm. transverse to the connection from C_2 to C_1 are preferably at least equal to:

$$0.7\cdot L\cdot B/Q,$$

wherein B is the dimension in mm. of an aperture in the central part of the mask; and

L is the distance in mm. between C_1 and C_2; and

Q is the distance in mm. between the central part of the mask and the central part (C_2) of the support.

An advantage of this preferred solution is that a possible loss of light due to the divergence of the beam is compensated for at least for the greater part by the choice of comparatively large transverse dimensions of the light source.

With regard to these transverse dimensions for the light source the following can be stated with reference to FIG. 1. In this FIG. 1 the reference C is the diameter of a luminous surface element which is provided at a distance P from a mask M, the distance between mask M and a screen S being denoted by Q. An aperture in the mask is circular and has a diameter B. The diameter between the limit of the half-shadow at S and the unexposed parts is indicated by D max. The cone bounded by the circumference of the aperture of the mask of diameter B and the center of C as a tip terminates on S in a circle of diameter Do.

Now it can be derived that $D\max=(LB+CQ)/P$

and $Do=LB/P$

This yields: $D\max/Do=1+CQ/LB$.

Acceptable values for $D\max/Do$ are $D\max/Do \leq 1.6$. Hence in the case without a negative lens there should apply that

$CQ/LB \leq 0.6$, that is to say, $C \leq 0.6\ LB/Q$.

When using the negative lens according to the invention the image of C is replaced by C', wherein $C' \leq 3/4\ C$.

Thus in that case $3/4\ C \leq 0.6LB/Q$ or $C \leq 0.8\ LB/Q$.

In this preferred case the inventors draw the lower limit at $C=0.7LB/Q$ by which is meant that a light source is used having larger transverse dimensions than is common practice in those cases in which no lens according to the invention is provided.

The lens of an exposure device according to the invention has preferably a concave boundary surface facing the light source wherein the center of curvature of the boundary surface lies on the line of connection between the light source and the center of the lens and wherein the second boundary surface of the lens is part of a convex surface, the center of this convex surface being located on a straight line through the light source and the center of the lens, the second boundary surface having a convex shape and the conditions:

$$R_1=v/(1+n) \text{ and } R_2=(1+(1/n)\ R_1+t$$

being substantially satisfied

wherein: R_1 is the radius of curvature in mm. of the first boundary surface; and

v is the distance in mm. between the center C_1 and the lens; and

n is the relative refractive index of the material of the lens for the wavelength range of the light from the light source; and

R_2 is the radius of curvature in mm. of the second boundary surface; and

t is the thickness in mm. of the central part of the lens.

If both conditions are satisfied the optical system is aplanatic. A light ray then impinges upon the second boundary surface of the lens at a straight angle. An advantage of the aplanatic system is that at least one point of the light source is projected without error.

In order that the invention may be readily carried into effect an embodiment thereof will now be described in detail by way of example with reference to the accompanying diagrammatic drawings in which:

FIG. 1 shows a figure already described and relating to the course of the light rays from a luminous surface element having a diameter C,

FIG. 2 is a diagrammatical cross section of an exposure device according to the invention;

FIG. 3 shows a few details of the exposure device of FIG. 2 at an enlarged scale;

FIG. 4 shows a light distribution of a tip of a light conductor of the exposure device of FIG. 2.

In FIG. 2 the reference numeral **1** denotes a substantially closed container of approximately 1 m. height. The reference numeral **2** denotes a cover for this container. This cover **2** is provided with an aperture **3**. Three or more stops **4** (one of which is visible in FIG. 2) and a positioning notch **5** are provided near the aperture **3**. A screen **6** is urged against the stops **4** with the aid of a notch **5**. This serves to have the screen **6** occupy a given position. The screen **6** is a future 25-inch image screen of a color television display tube. A mask **7** which is provided with a plurality of holes **8**, **8'** etc. is provided at a short distance from this screen. The container **1** contains a secondary light source **9** which is formed by the tip of a conelike light conductor **10**. The source **9** radiates light via a negative lens **11** (according to the invention) and via a correction lens **12** through the apertures **8**, **8'** etc. of the mask **7** onto the screen **6**. A photosensitive layer provided on the side of screen **6** facing the cone **9** is then exposed. This layer consists of a photoresist which is soluble in water and contains a bichromate salt as a sensitizer. The correction lens **12** serves for adaptation of the direction of the light rays to the direction of the deflected electron beam (in the tube to be manufactured). A filter layer **12*a*** whose permeability increases from its center towards the edge is provided on the lens **12**. The reference numerals **13** and **14** denote two electric wires which serve to supply an electric discharge lamp which projects light onto the base plane of the cone **10**. This lamp and the cone **10** are mounted in an auxiliary member **15** which is supported by a few vertical consoles **16** and **17**. The distance between the center C_1 of the tip of the cone and the lens **11** was 25 mm. in a certain embodiment. The distance between C_1 and a point C_2, which represents the center of screen **6**, was then 352 mm. An aperture of the mask near the point C_2 had a diameter of approximately 0.29 mm. The central portion of the lens **11** had a thickness of approximately 3 mm. The tip **9** of the cone had a diameter which was approximately 1.5 times larger than is common practice, namely 6 mm.

In FIG. 3 the lens **11** and the tip **9** of the cone of FIG. 2 are shown at an enlarged scale. In this Figure the reference H represents the centerline through the center of the tip C_1 of the cone and the center of the lens **11**. The reference **0** is a point of intersection of this centerline H with the lens **11**. The reference K_1 denotes the center of curvature of the first boundary surface and K_2 denotes the center of curvature of the second boundary surface of the lens **11**. The reference C_1 JG denotes the course of a ray of light from the tip of the cone through the lens **11** to the screen **6**. This ray of light intersects the second boundary surface at a straight angle.

The radius of curvature of the first boundary surface was 10 mm. in the relevant case and it was 19.8 mm. for the second boundary surface. The refractive index n of the lens was 1.48 for the light from the lamp.

It can be calculated from these data that, viewed from the center C_2 (see FIG. 2), the reduction M of the tip **9** of the cone by the lens **11** is approximately 0.68, that is to say, it is less than three-fourths so that $f<3v$ is satisfied. Furthermore, the size of the tip of the cone (6 mm.) is larger than $0.7 \cdot LB/Q=5.4$ wherein L is the distance between the tip of the cone and the point C_2 (**352** mm.) and B is the diameter of the aperture of the mask (diameter 0.29 mm.) at C_2, and Q is the distance between mask and screen (13,5 mm.).

In FIG. **4** the reference C_1 denotes the central point of the previously mentioned cone **10**. The reference I_0 in this Figure denotes the light intensity into the direction of the point C_2. The reference $T\beta$ denotes the light intensity of the tip of the cone into the direction of a point on the edge of the support. This direction constitutes in the embodiment an angle $\beta=45°$ with the axis C_1C_2 through the point C_1. The magnitude of the light intensity into other directions is denoted by the curve **21** in FIG. 4. This curve shows that the light intensity is smaller at a greater angle with C_1C_2. By interposition of the lens **11** (see FIGS. 2 and 3) the ratio between the light intensities towards C_2 and into the direction β is improved, however. This is apparent, for example, from FIG. 3. In fact, when using the negative lens the light intensity into the direction β is generated by a ray of light which is radiated by the cone **10** at an angle α, that is to say, at a smaller angle. The quantity of light actually radiated by the cone **10** in combination with the lens **11** into the direction β is denoted by I_R in FIG. 4. This light intensity is $I_R=\cos \beta/\cos \alpha \cdot I\alpha$. This light intensity I_R is greater than the light intensity $I\beta$. In the relevant embodiment α was approximately 28°40'.

The result of the introduction of the negative lens is therefore that the filter layer which is generally applied on the lens **12** (see FIG. 2) may be less thick in the center of this lens. In the case of FIG. 2 referred to the light absorption in the center of the lens **12** was only approximately 2.5 times that of the edge of the lens **12**. As a result less loss of light occurs in the filter layer. In combination with the cone **9** having a tip diameter which is approximately 1.5 times larger than is common practice this leads to shorter exposure times of the screens **6**.

Since the lens is an aplanatic lens as is apparent from the mentioned radii of curvature and distances, at least the point C_1 is displayed on the screen **6** without error. This is advantageous for obtaining phosphor dots of the desired shape on the screen.

What is claimed is:

1. An exposure device for projecting aperture patterns from a substantially planar mask onto a photosensitive layer on a picture screen for cathode-ray tubes comprising a conical light source having a longitudinal axis orthogonal to the plane of said mask, and a substantially rotationally symmetrical negative lens between said light source and said mask, the focal length f in mm. of said lens satisfying the condition:

$$f<3v$$

wherein v is the distance in mm. between the center of the light source and the lens, said lens diverging the light radiated from said light source to enlarge the transverse dimensions of said light source as viewed from said mask, and wherein the light intensity I_B from said light source to a point on the edge of said mask satisfies the condition:

$$I_B<\cos B/\cos \alpha \cdot I\,\alpha$$

wherein B is the angle between a line connecting the centers of said light source and said mask and the edge of said mask, $I\,\alpha$ is the light intensity at angle α with said line connecting the centers of said light source and said mask, and α is given by the relation

$$\sin \alpha=(1+v/f)^{-1} . \sin B,$$

said light source having dimensions which substantially compensate for any loss in brightness resulting from the divergence of he light radiated from said source.

2. An exposure device as claimed in claim **1** wherein said photosensitive layer comprises a photoresist that is soluble in

water and contains a bichromate salt as a sensitizer, and the dimensions of said light source in mm. are at least equal to

$$0.7 \cdot LB/Q$$

wherein: B is the diameter in mm. of an aperture in the central part of said mask, L is the distance in mm. between the centers of said light source and said mask, and Q is the distance in mm. between the centers of said mask and said screen.

3. An exposure device as claimed in claim **1** wherein said negative lens comprises a concave boundary surface facing said light source having a center of curvature lying on a line connecting the centers of said light source and said lens, and a convex boundary surface opposite said light source having a center located on a straight line through said light source and center of said lens, said convex boundary surface substantially satisfying the condition

$$R_1 = \nu/(1+\nu) \text{ and } R_2 = (1+1/n)\, R_1 + t$$

wherein: R_1 is the radius of curvature in mm. of the concave boundary surface, ν is the relative refraction index of the material of the lens for the wavelength range of the light from the light source R_2 is the radius of curvature in mm. of the convex boundary surface and t is the thickness in mm. of the central part of the lens.

4. An exposure device as claimed in claim **1** further comprising a corrective lens between said lens and mask for adapting the direction of said light radiated from said light source to the direction of deflected electron beams, said corrective lens having a filter layer, the permeability of said filter layer increasing from its center towards its edges.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,628,429 Dated December 21, 1971

Inventor(s) PIET G. J. BARTEN AND JOHANNES C. A. VAN NES

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In the title page, change co-inventor's name from

"Johannes Cornelis Adrianus Vannes" to

--Johannes Cornelis Adrianus Van Nes--.

Signed and sealed this 16th day of May 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

PO-1050
(5/69)

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