July 19, 1938. J. C. BATCHELOR 2,124,224

ELECTRONIC TUBE

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Fig. 1.

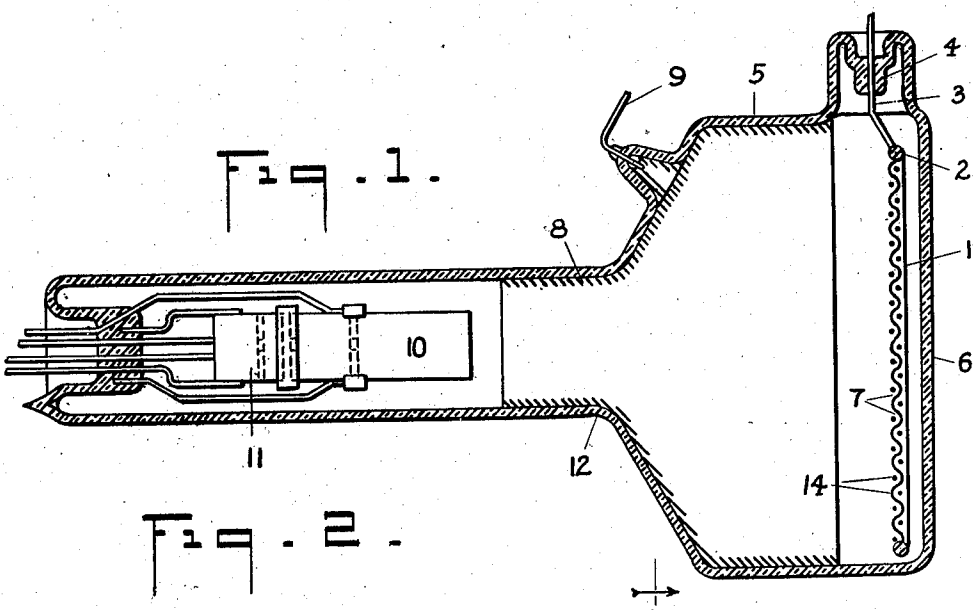


Fig. 2.

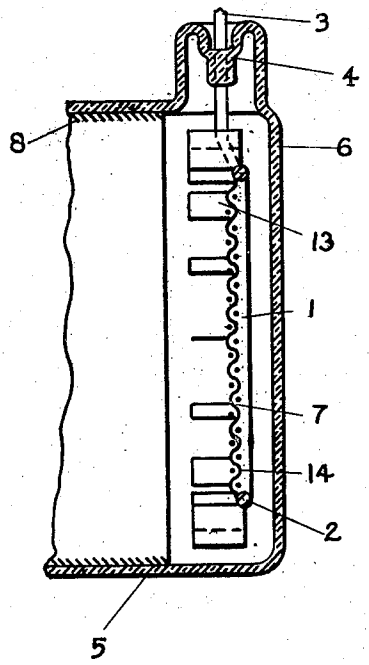
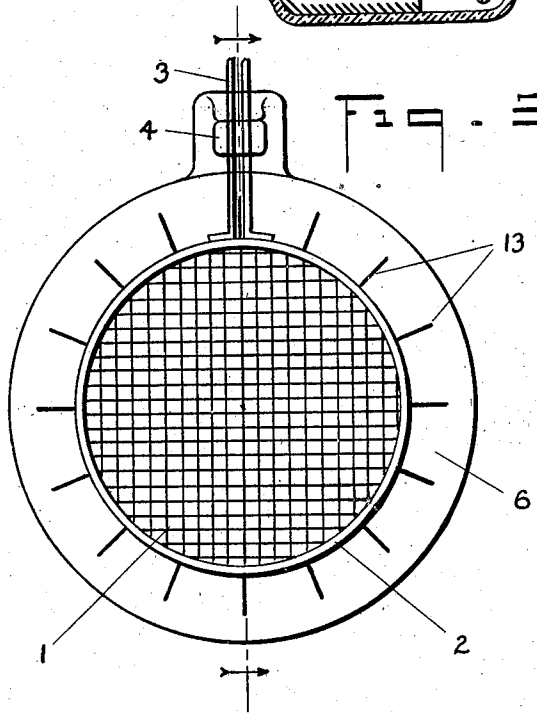


Fig. 3.



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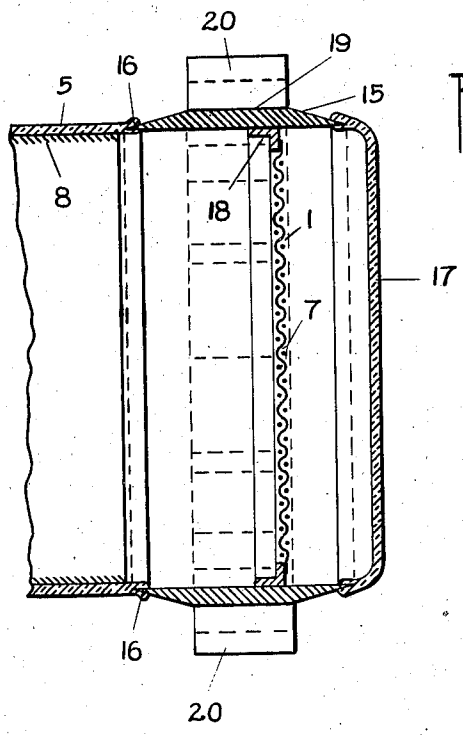
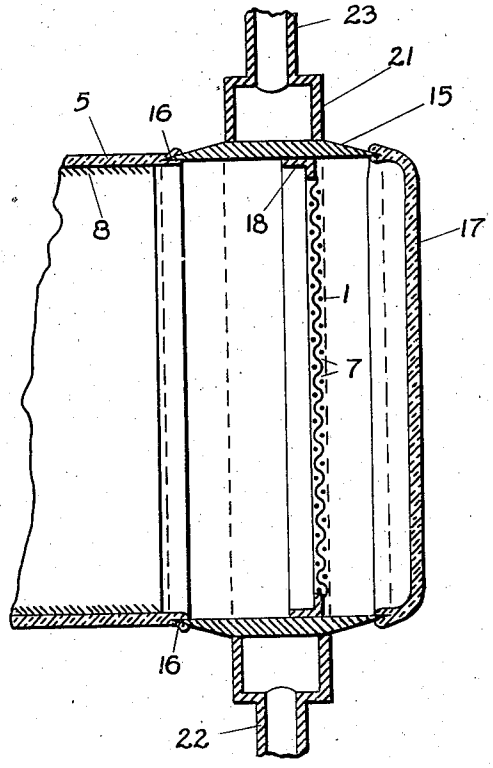


Fig. 4.

Fig. 5.



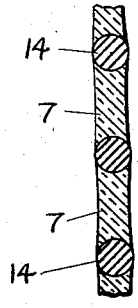


Fig. 6.

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Fig. 7.

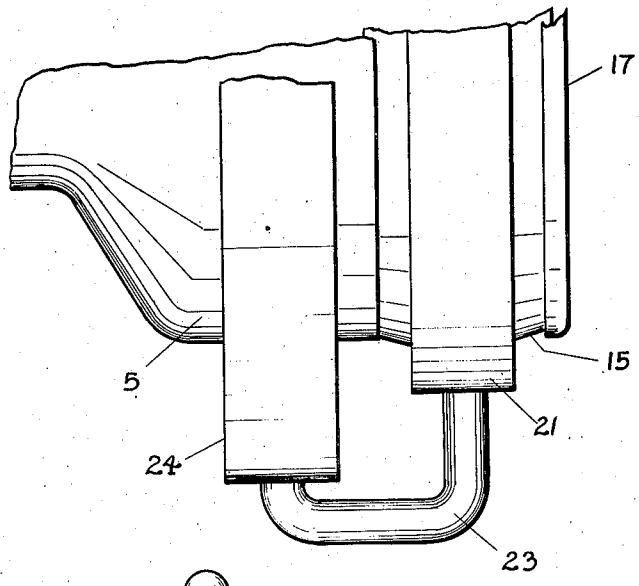
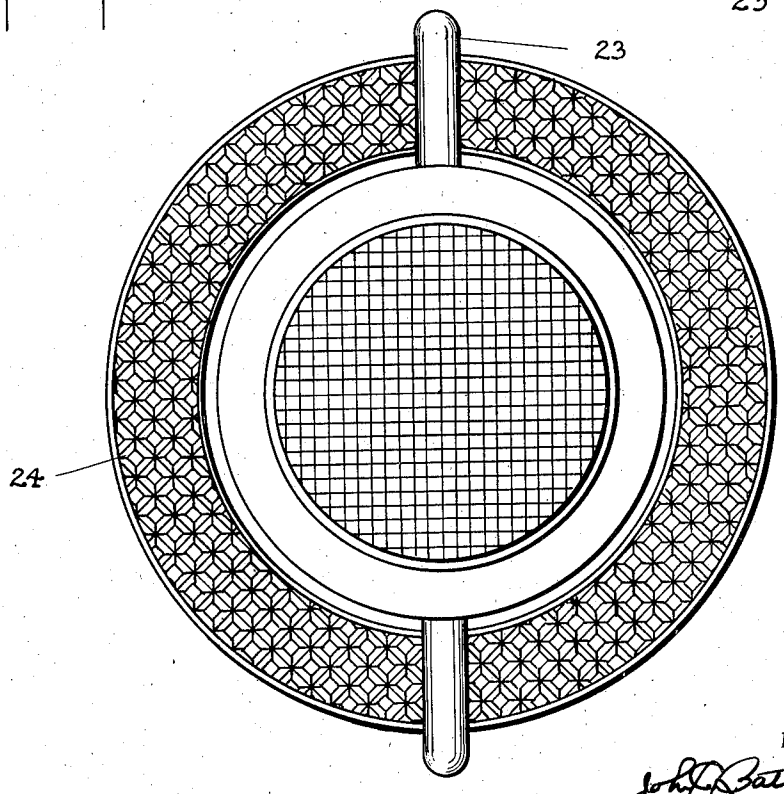


Fig. 8.



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UNITED STATES PATENT OFFICE

2,124,224

ELECTRONIC TUBE

John C. Batchelor, New York, N. Y.

Application February 1, 1935, Serial No. 4,494

4 Claims. (Cl. 250—27.5)

My invention relates to fluorescent screens, and, more particularly, to such screens for use in cathode ray tubes designed to produce high intensity illumination suitable for the production of television images which may be enlarged by projection.

It is customary in the art to produce cathode ray tubes having a light producing member comprising a film of fluorescent material such as willemite, zinc sulphide or the like, deposited upon an inner surface of the glass envelope of the tube or on a mica or other light transmitting plate within the envelope of the tube, such that the fluorescent film may be scanned rhythmically by a modulated electron beam to produce upon the fluorescent screen a visible image of a remotely analyzed object.

The efficiency of the transformation of the kinetic energy of the moving electrons of the electron beam into visible radiation through the process of fluorescence is relatively low, and the area of impact of the electron beam is relatively small, so that each elemental area of a fluorescent screen is required to dissipate the heat energy which arises from the inefficient energy transformation in the fluorescent screen. Because of the relatively low thermal conductivity of the fluorescent material, of the glass or other material upon which the fluorescent material is deposited and of the vacuum in the space within the tube adjacent the screen, there is but little removal of heat by conduction, and, consequently, the temperature of the fluorescent screen itself will rise to such a value that the heat will be dissipated by radiation.

It is known that the efficiency of cathodo-luminescence decreases quite rapidly when the temperature of the luminescent material is increased, and for this reason there is a maximum intensity of electron bombardment beyond which no further increase in luminosity occurs with increase in bombarding intensity. Furthermore, even in the absence of such a decrease in efficiency with temperature, there is another temperature at which the chemical and/or crystalline structure of the fluorescent material is so altered that its ability to fluoresce is permanently eliminated, and this temperature must never be reached by a fluorescent screen in a cathode ray tube.

With the foregoing in mind, it is an object of my invention to provide a cathode ray tube capable of producing a small television image of such luminous intensity that it may be projected to a large size with sufficient brilliancy for convenient viewing. A further object of my invention is to provide a cathode ray tube having a fluorescent screen so prepared and mounted that the heat generated therein may be dissipated easily, thereby making possible greater intensity of illumination and reducing the possibilty of destroying, by overheating, the ability of the fluorescent screen to produce light under the influence of electronic bombardment.

In accordance with my invention, I prefer to use as a fluorescent member in a cathode ray tube, a wire gauze or perforated metal plate, in the interstices of which has been placed material capable of producing fluorescent light when struck by rapidly moving electrons. In such a member the metal of the gauze or plate serves effectively to transfer the heat generated by the electron impact away from the point of impact and distribute it over the entire area of the screen. Further, in accordance with my invention, I have provided such a fluorescent member with heat radiating members attached for the purpose of radiating the heat generated in the fluorescent member. Still further, I have, in cases where the energy to be dissipated is greater than can be radiated through the vacuum of the tube, provided means for heat conductive communication between the metal of the fluorescent member and heat radiating members disposed externally to the tube so that the heat may be transferred conductively to the air about the tube. For use in cases where extreme amounts of heat are to be removed from my fluorescent member, I have provided liquid cooling means external to the tube and in heat conductive communication with the fluorescent member.

In order to explain my invention more fully, I shall refer to the appended drawings, of which Figure 1 is a sectional view of one embodiment of my invention; Figure 2 is a sectional view of the fluorescent screen portion of a modified embodiment, the section being taken on the line 2—2 in Figure 3; Figure 3 is an end view of the embodiment shown in Figure 2; Figure 4 is a sectional view of the fluorescent screen portion of a further modified embodiment; Figure 5 is a sectional view of the fluorescent screen portion of a still further modified embodiment; Figure 6 represents an enlarged sectional view of a fluorescent screen; Figure 7 is a full view of a portion of another embodiment of my invention; Figure 8 is an end view of the embodiment shown in Figure 7.

In the cathode ray tube shown in Figure 1 a disc 1 of woven wire mesh is mounted on the metal support ring 2 which is in turn carried by the lead-in wires 3 in the stem 4 which is in

turn sealed into the glass envelope 5 in a manner such that the disc 1 will lie adjacent the window 6 in the end of the envelope 5.

Prior to the insertion of the disc 1 into the tube 5 the interstices of the disc 1 are filled with a film 7 of fluorescent material, as shown in Figure 6. The film 7 may be introduced into the interstices of the disc 1 by any of a number of methods. For example, the disc 1 may be dipped into a suspension of fluorescent powder in a liquid in which the material is insoluble, then withdrawing the mesh disc allowing the interstices to remain filled with the suspension which, upon drying of the suspending liquid, will leave a film of fluorescent material within the interstices of the gauze. As an alternate method, a suspension of the fluorescent material may be painted or sprayed onto the screen in such a manner that the interstices will be filled with the suspension, and the liquor allowed to evaporate. Another method comprises rolling the fluorescent material, either dry or in a suspending liquor, into the mesh by means of a suitable roller. Although the fluorescent material will in general remain in position without the aid of any binding material, it is possible in cases when still greater tenacity is required to introduce a small quantity of any suitable binder such as sodium silicate in water. As a result of the presence of the metal mesh within the screen any heat which is generated locally is very rapidly conducted to the remaining area of the screen, and the fluorescence of the spot being bombarded is not, therefore, impaired by excessive temperature.

When consideration is given to the facts that the thermal conductivity of metals is of the order of 0.1 to 1.0 calory per second per centimeter cube per degree centigrade whereas that of glass is of the order of 0.002 calory per second per centimeter cube per degree centigrade, it may be seen that the insertion of my cooling members in screens is advantageous when the greatest distance from the fluorescent material to metal is 0.1 inch and the thermal conductivity of the metal is 0.1 calory per second per centimeter cube per degree centigrade. In this case the dissipation of heat from the fluorescent screen is in excess of that from a screen deposited directly upon a glass wall of a cathode ray tube 0.1 inch thick and the outer surface of said wall exposed directly to air.

The interior of the tube 5 is coated with a film 8 of metal preferably darkened on the inside to prevent internal reflection of light from the screen. Contact is made to the metallic coating 8 by the wire 9 sealed into the bulb, and the coating serves as an accelerating and focusing electrode for the electrons coming from the electron gun 10. The number of electrons in the beam is controlled by the control electrode 11. The electron beam may be caused to scan the screen 1 by electromagnetic fields applied adjacent the neck of the tube in the region 12, or as an alternate method, deflecting plates, (not shown) may be inserted in the neck of the tube in the region 12.

In the event the electron beam is of considerable intensity or the voltage is sufficiently high that the total heat reduces the quantity of fluorescent light, heat radiating fins 13, Figures 2 and 3, have been attached to the screen supporting ring 2 for the purpose of dissipating the heat transmitted to the ring 2 from the wires 14 in the screen 1. These fins are of any heat conducting material such as copper, and are preferably blackened by any suitable process such as carbonization.

In the case of tubes in which the energy to be dissipated from the screen is very large, my tube is built as shown in Figure 4. A section of copper cylinder 15 is inserted at the end of the glass tube at 16 by a glass to copper seal, and said copper cylinder carries at its opposite end the plate glass window 17. Mounted by means of the metal ring 18 on the cylinder 15 is the screen 1 carrying the fluorescent material 7. This type of construction provides the peripheral cooling surface 19 exposed to the air, and, when larger amounts of heat are to be dissipated, I have provided radial fins 20 to cause additional cooling. In some extreme cases I have provided a water or liquid coolant jacket 21 in Figure 5 having a liquid inlet 22 and outlet 23. In this case I have found it convenient to provide a local radiator 24 as shown in Figures 7 and 8, for cooling the liquid. It should be noted that in the embodiment shown, the radiator 24 is disposed for free circulation of air when the tube is mounted in a vertical position; the radiator may, however, be built to provide suitable cooling for any desired angle of mounting. This radiator may, further, be provided with a fan for cooling it, or it may depend entirely upon normal air circulation; a pump for circulating the liquid may be provided if desired. Obviously the cooling liquid need not be water, but may be any liquid of suitable thermal capacity, viscosity and chemical inertness. For example, a liquid may be chosen having sufficiently low freezing temperature that danger of freezing will be eliminated when the instrument is in storage. The cooling system may be hermetically sealed in order to prevent loss of coolant by evaporation or spilling.

From the foregoing it will be seen that in Figures 2, 3, 4, 5, 7 and 8, associated with the mosaic fluorescent screen structure comprising wire gauze or a perforated metal plate and fluorescent material disposed in and closing the relatively minute openings as described, there are means in direct heat conductive relation with respect to the screen structure only at the outer edge portion thereof, and that such means operate to induce heat removal from each of the individual elemental sections of the mosaic in directions substantially radially outwardly from the center of the screen structure.

It is apparent that any suitable metal may be used as the material for the wire gauze carrying the fluorescent material; I prefer copper or silver because of their relatively high thermal conductivity and their stability at elevated temperatures in vacuum. Further, the gauze may be replaced by a perforated metal plate.

A compromise must obviously be effected in choosing the correct ratio of wire area to opening area in the gauze used. When the ratio becomes too large the electrooptical translation efficiency becomes quite low because of the absorption of electrons by the wires of the gauze; when the ratio is too small the ruggedness of the screen suffers because of the relatively large expanse of unsupported fluorescent material, and also the cooling effect of the wires is not as great as is desirable because of the reduced cross sectional area of the wires. I have found a region from unity to one-tenth to be suitable values for this ratio of wire area to opening area, but the range may be extended under favorable conditions. It is apparent that as this ratio

grows smaller the cooling efficiency of the system becomes smaller because of the relatively low heat conductivity of the fluorescent material itself. Heat generated by the center of any span 7, Figure 6, of the fluorescent material in a single interstice must traverse more of itself to reach the wires 14 as the ratio becomes smaller, and consequently the size of the openings must be made sufficiently small that the fluorescent material at the center of any interstice will not become too hot. I have found it convenient to use a woven wire mesh having several interstices in the area of one element of the image being reproduced. Thus, if, for example, a four hundred line picture were to be reproduced in a screen area two inches square, there would be 200 lines per lineal inch of mesh, and if it were desired that each picture element should cover four interstices of the mesh, there would be required two interstices in each direction per image element so that the mesh would have 400 interstices per lineal inch.

Tubes in use prior to my invention have shown marked decrease in the electrooptical efficiency of fluorescence when the energy of bombardment is greater than one watt per square inch of area in the fluorescent screen, whereas, with the embodiment of my invention in an otherwise similar tube, substantially constant electrooptical efficiency is maintained with intensities of bombardment in excess of 25 watts per square inch, and thus, the factor limiting the intensity of bombardment in such tubes is no longer the ability of the fluorescent screen to dissipate heat, but is the design of an electron gun capable of concentrating sufficient current in a sufficiently small area.

A further advantage of the presence of the gauze is the improvement in the collection of the secondary emission from the screen and the resultant more efficient utilization of the beam. In general, a tube of this nature depends upon secondary emission to remove the charge which would otherwise accumulate on the screen, and it is apparent that the gauze will collect the secondary electrons with less space charge impedance than would the metallic coating 8 whose function that collection would be in the absence of the gauze. The efficiency of this collection may be still further increased by the removal of the fluorescent material from the wires 14 on the back or bombarded side of the screen 1.

My invention is in no way limited in fluorescent material. Almost all fluorescent materials lose some efficiency above certain temperatures, and it is therefore advisable not to exceed those temperatures in operation. For this reason my invention should be considered to be applicable to any fluorescent material exhibiting this characteristic, and to any cathode ray tube using one or more of these materials.

I claim:

1. In a cathode ray tube, a fluorescent screen, an electron gun whereby an electron beam may be caused to impinge said screen, said screen comprising a member formed of heat conductive material and having openings therein and fluorescent material in said openings, a portion of the surface of said member being exposed to electronic bombardment from said electron beam whereby secondary electrons may be drawn from said fluorescent material.

2. In a cathode ray tube, a fluorescent screen comprising a member formed of heat conductive material having a thermal conductivity of the order of 1.0 calory per second per centimeter cube per degree centigrade and said member having openings therein, a fluorescent material supported by said member in said openings and in intimate contact with said member.

3. In a cathode ray tube, a fluorescent screen comprising a member formed of heat conductive material having openings therethrough and fluorescent material supported by said member in said openings, the ratio of the total projected area of said heat conductive material in the plane of the member to the total area of the openings in said plane being in the region from unity to one-tenth.

4. In a cathode ray tube, mosaic fluorescent screen structure comprising a member formed of heat conductive material and provided with relatively minute openings therethrough, fluorescent material disposed in and closing said openings, the fluorescent material in the individual openings being exposed on both sides of said screen structure, and means associated with said screen structure and in direct heat conductive relation with respect thereto only at the outer edge portion thereof and operating to induce heat removal from each individual elemental section of the mosaic in directions substantially radially outwardly from the center of said screen structure.

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