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CATHODE RAY TUBE

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3 Sheets-Sheet 1

FIG. 2.

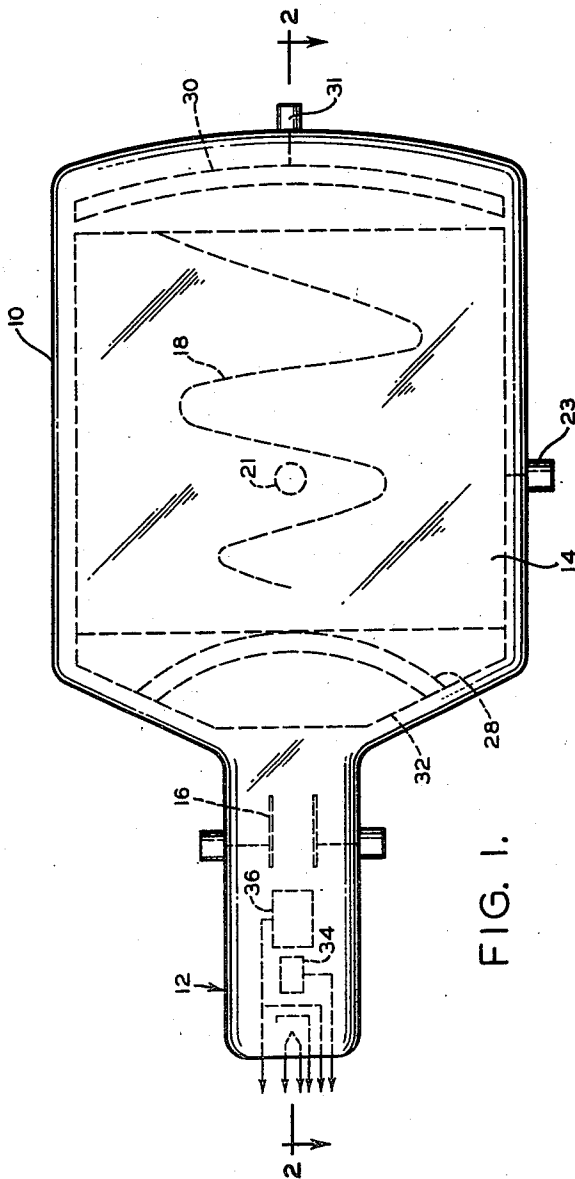
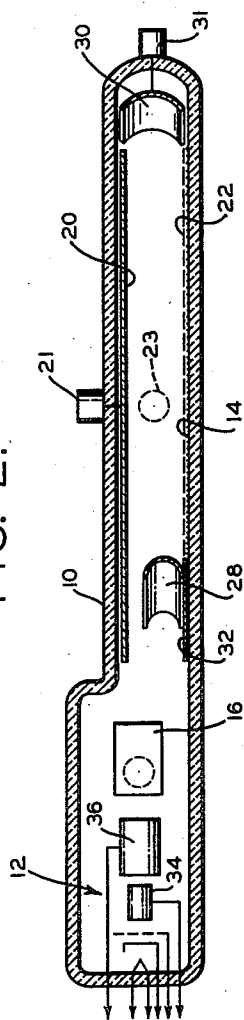


FIG. 1.

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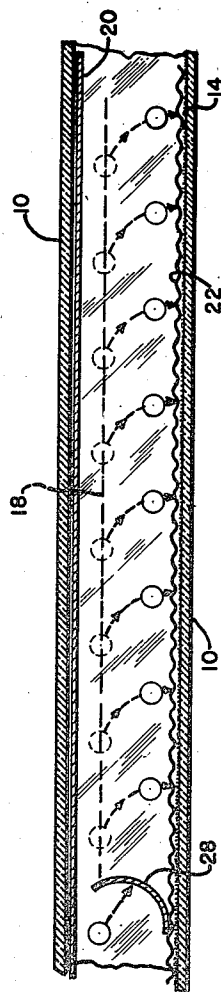
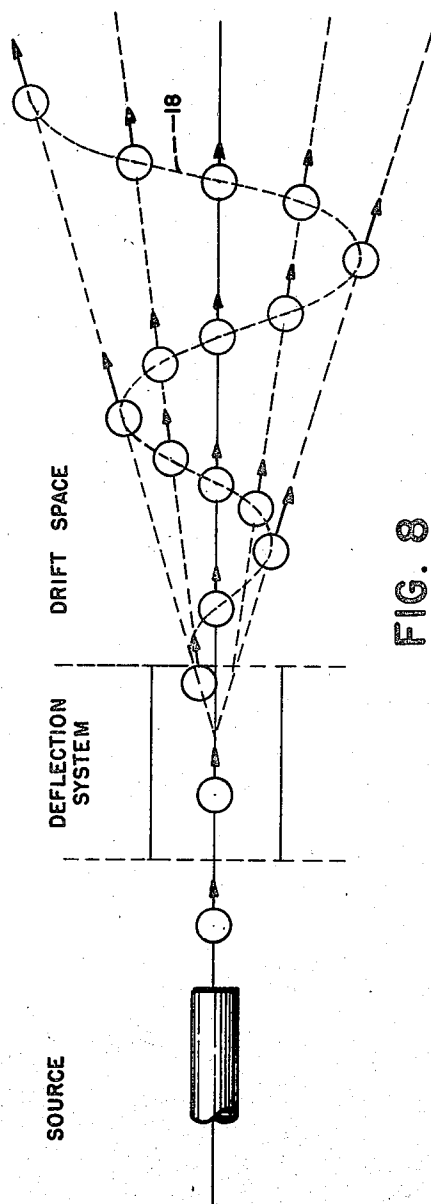
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3 Sheets-Sheet 3



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CATHODE-RAY TUBE

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amended April 30, 1928; 370 O. G. 757)

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This invention relates to cathode ray tubes, and more particularly to tubes used for examining high frequency phenomena.

The primary object of the invention is to generally improve cathode ray tubes.

To examine wave forms and the like on a conventional cathode ray tube it is necessary to employ a sweep wave which, for correct reproduction of the wave form, should be linear in character. This has been done successfully at radio frequencies, but difficulty arises in obtaining such a saw tooth wave at higher frequencies in the VHF or UHF bands. One object of the present invention is to eliminate the need for a linear sweep wave.

A more particular object is to provide a cathode ray tube and associated circuits which will make it possible to picture and examine waves of a frequency higher than those conveniently examinable in conventional cathode ray tubes.

To accomplish the foregoing general objects, and other more specific objects which will hereinafter appear, our invention resides in the cathode ray tube elements with associated circuits, and their relation one to the other as are hereinafter more particularly described in the specification. The specification is accompanied by drawings in which:

Fig. 1 is a front elevation of a cathode ray tube embodying features of our invention;

Fig. 2 is a longitudinal section taken in the plane of the line 2—2 of Fig. 1;

Fig. 3 is a block diagram explanatory of the invention;

Figs. 4 and 5 show a modification of the invention using a resonant cavity as a deflection means; and

Figs. 6 and 7 indicate still another modification of the invention using Lecher wires as a deflection means; and

Figs. 8 and 9 are diagrammatic sketches of sections of the tube which explain the operation of the cathode ray tube embodying our invention.

The mode of operation of our cathode ray tube may be stated generally as using the forward velocity of the electrons in the electron beam of the tube to provide the time axis sweep for a wave-form presentation on the screen of the tube. Since electron velocity is usually very great, it is possible with our cathode ray tube to observe very high frequency waves or pulses of extremely short duration.

For an understanding of the operation of the tube, a corollary may be made between the electron particles of the beam emitted from an elec-

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tron gun, and a stream of marbles, for example, being projected from a source with a known initial velocity. Fig. 8 illustrates schematically a system analogous to the electron beam controlling apparatus of a conventional tube except that a stream of marbles has been substituted to represent the stream of electrons. The marbles are all given a constant initial forward velocity by the projection source. Assuming that an alternating force is acting on the deflection system, the marbles are given a component of velocity which is transverse to the initial velocity, thus giving the marbles a resultant velocity vector which depends on the magnitude of the deflection field as the marbles leave the deflection system.

Since the deflection field was assumed to vary in an alternating fashion, each successive marble will be aimed in a different direction as it leaves the deflection system due to the difference in the transverse velocity component imparted to each successive marble. This will especially be true if the forward velocity of the marbles is slow in comparison with the rate at which the deflection field is changing. After leaving the deflection system, however, the individual marbles travel in straight lines because they are not subject to a deflection force while moving through the so-called drift space. The collective pattern of the stream of marbles in the drift space in a reproduction of the field variations of the deflection system. The variation of the field which was a function of time is recorded in the drift-space as a variation in the marble displacement and is a function of the distance of each individual marble from the deflection field. The collective pattern formed by all the marbles is indicated by the diverging sinusoidal dotted line 18, while the arrows on each marble represent its resultant velocity vector. The divergence of the marbles is caused by the variation of the resultant velocities of the marbles as they pass through the deflection system. This distortion, however, occurs in a predetermined manner, and the tube thus will yield as much useful information as it would if the distortion were not present.

The remaining problem is to interpret or observe the information presented by the pattern of marbles appearing in the drift space. The simplest method is to locate a screen or the like parallel to this pattern and to project the marbles onto it in the same configuration as they appear in space. A number of methods, which will hereinafter be described, may be used to cause this projection. Generally, however, the drift space configuration is "side swiped" by some means onto

a screen, a photographic plate, or the like, in such a manner that it is registered thereon.

A diagrammatic view of the narrow cross section of the tube is shown in Fig. 9 to illustrate in a general way the projection operation of the tube. A predetermined length of the stream of marbles (sufficient to extend approximately the length of the tube) is allowed to enter the drift space at a time, and it is then projected laterally against the screen, indicated by wavy line at 22. The marbles shown in dotted circles in Fig. 9 indicate a transverse view of the deflection pattern 18 of Fig. 8, before a projection force is applied to the pattern. The solid circles indicate the position of the marbles a short time after the projection force has been applied, and the dotted lines connecting the respective dotted and solid circles indicate the approximate paths the marbles take in striking the screen 22. Since only a specified portion of the stream of marbles is to be examined at a particular time, a cup-shaped trough 28 is provided to catch any oncoming marbles which appear immediately following the "side-swiping" operation. This feature minimizes distortion that would be caused by unwanted marbles appearing in the drift space.

The basic principle of operation of the actual tube, using electrons instead of marbles is exactly the same as described above.

Referring particularly to Figs. 1 and 2, the cathode ray tube comprises an evacuated envelope 10, an electron gun generally designated 12, and a flat fluorescent screen 14 disposed generally parallel to but off-set somewhat from the axis of the gun 12. Appropriate deflection means 16 are employed to deflect the beam from gun 12 in a plane generally parallel to screen 14. The tube further comprises projection means to project a substantial length of the deflected beam laterally against the screen 14 for observation. A typical screen picture is indicated in Fig. 1 by the dotted line 18.

As here illustrated, the projection means comprises a flat plate or electrode 20 on one side of the cathode ray beam, and a perforate or grid-like electrode 22 on the other side of the beam between the beam and the screen 14. Referring to Fig. 3, by impressing a pulse such as is indicated at 24, from pulse generator 27 on the projection electrodes, the electron beam from the gun, already deflected in accordance with the wave to be examined, is projected laterally toward the observer until it hits the fluorescent screen.

The flow of additional electrons to a point behind the screen is preferably interrupted at this time, and in the present case the interrupter means is a catcher device, as is indicated at 28 in Figs. 1 and 2. The tube further comprises a collector 30 for collecting any residual electrons which pass beyond the screen. Collector 30 has the same potential as the accelerating anode 36.

In the tube here illustrated, the electrodes 23 and 30 are both trough-like electrodes, preferably curved about a point in the center of the space between the deflecting electrodes 16. Viewed as in Fig. 2, the collector electrode 30 extends all the way across the tube, whereas the interrupter electrode 23 is narrower, and is so designed that the electron beam from the gun normally misses it. However, when the strong projection pulse 24 (Fig. 3) is applied, and the beam is projected towards the screen, further electrons coming from the gun are trapped by interrupter 28. The latter is secured to a plate 32 forming a part of the grid structure 22 previously referred to, and is

at the same potential as the grid, both being made highly positive by the pulse intermittently applied thereto.

As will be seen in Figs. 1, 2 and 3, the projection plate 20 is connected to a suitable terminal 21, the grid 22 is connected to another terminal 23, and the collector 30 is connected to a terminal 31.

Focusing means is preferably provided between the gun 12 and the deflection means 16. In the present case this consists of focusing cylinders 34 and 36, but magnetic focusing means may also be employed. In the present tube it is desired to focus the beam, so far as possible, throughout its length, rather than merely at a spot, and the design should aim for a narrow beam.

The pulse repetition frequency may be any convenient value, the only requirement being that it be high enough to produce a persistent image on the screen. A frequency of 60 cycles per second is adequate. The successive images on the screen should be superposed or in register, and for this purpose the projection pulses should be sub-multiple synchronously related to the frequency of the wave being examined. This is indicated in Fig. 3 in which the equipment 25 under test is connected to the deflection means 16, and also to a sync oscillator 26 which in turn is connected to a pulse generator 27. This energizes the projection plate and grid. In many cases the equipment 25 under test, for example, a magnetron, multivibrator or any device that may be pulsed, is of such a nature that it will follow in synchronism with the sync oscillator 26. In other cases where the input wave is continuous or independent of any synchronizing pulse, the sync oscillator 26 must be so designed as to fall in step with the input wave.

In such case the sync oscillator 26 and pulse generator 27 together must count down from the high to the low projection frequency. If the input frequency supplied to deflection means 16 is stable, it is possible to obtain the desired synchronous relation by using a stable local oscillator, thus obtaining a low radio frequency beat which in turn may be counted down for the projection pulse.

By eliminating the need for a linear sweep wave, the next limiting factor on the frequency of the wave to be examined is the deflection means 16. The use of simple deflection plates shown is convenient, but involves capacitance between the plates, and also involves the transit time of the electrons passing between the plates. To reduce the capacitance and the transit time the plates may be shortened, but this will require a greater potential on the plates. In ultimate form the plates may be replaced by a pair of wires forming a part of a resonant or Lecher line. This is indicated in Figs. 6 and 7, in which the neck portion 40 of the tube has a pair of wires 42 and 44 passing therethrough, said wires being tuned by an adjustable shorting bar 46. The opposite end of the wires are connected to the source of the wave being examined. It will be understood that the potential maximum is located within the neck 40 of the tube. This arrangement is useful in the VHF region.

Still another means for producing a high frequency deflection involves the use of a resonant cavity in lieu of deflection plates, and this is illustrated in Figs. 4 and 5. The cavity 50 is secured around the neck 52 of the tube, as shown in Fig. 5. The glass of the neck might be sealed directly to the cavity, but it is more convenient to preliminarily seal the glass of the neck to thin metal

discs, as shown at 54 and 56 in Fig. 4. The box 50 of the cavity is then made in two halves, one half being shown in Fig. 4. The split box is provided with clamping rings 58 and 60. When the parts are assembled together the box just fits between the discs 54 and 56. The rings 60 are screwed to the box and are thereby clamped against the exposed edges of the discs. By splitting the rings 58 and 66 in a plane perpendicular to the splitting of the box, the rings may be used to hold the halves of the box together, as well as to clamp the box to the discs 54 and 56.

The disc 54 has an aperture 62, and the disc 56 has a slot 64. The discs and box together make up the cavity. The cavity is excited in such a mode as to produce vertical deflection of the beam. This cavity arrangement is useful in the UHF region.

The cavity is excited by energy supplied through a coaxial cable secured at 66 and including a center conductor 68 terminating in a loop 70. Although no tuning means is shown, it will be understood that the cavity may be provided with a tuning slug and a control screw for the same, or other equivalent tuning means. For large changes of frequency, one box may be removed and replaced by another box of different size.

Theoretically, a single cycle of any periodic deflection voltage may be represented on the screen. The only requirement is that the velocity through the projection plate and grid be directly proportional to the frequency of deflection. The proportionality constant is such that the tube is readily applicable to frequencies in the VHF region.

If the length of the fluorescent screen is L , and all electrons are traveling toward the end collector with a velocity V_0 , then the pattern on the screen will be one cycle, if the electron transverses the distance L in the period of the deflection frequency. Expressed as a ratio:

$$V_0 = \frac{L}{t}; V_0 = Lf \text{ where: } t = \text{period} = \frac{1}{f}$$

Therefore a given screen dimension and frequency will determine the velocity needed to observe one complete cycle.

Or stated another way, the frequency of the applied signal may be readily determined by observing the number of complete cycles on the screen and knowing the accelerating voltage.

Since the electrons will travel in a straight line after leaving the vertical deflection plates, the time-space plot of the electrons will diverge. For example, if a sinusoidal voltage is applied to the deflection plates, the resulting pattern in the drift space, and thus on the screen, will be a diverging sine wave, as shown at 18 in Fig. 1.

Although the pattern is not a true representation of the input, it is distorted in a definite predetermined manner. Therefore one may obtain the same information from the screen as could be obtained from a true representation. If any deviation from the linear distortion is observed, the observer may conclude that the applied deflection voltage is distorted.

It is believed that the construction and operation, as well as the advantages of our invention, will be apparent from the foregoing detailed description. A wave form is examined by accelerating electrons to form a beam extending generally parallel to a screen, then deflecting the beam in a plane parallel to the screen in accordance with the wave form to be examined, and then intermittently projecting a substantial length of

deflected beam laterally against the screen for observation.

The tube utilizes the space-time position of deflected electrons to indicate the nature of the applied deflection voltage. It presents the space-time position of the deflected electrons on a fluorescent screen. It responds to deflection frequencies of much smaller periods than those that may be observed on a conventional cathode ray oscilloscope.

Focusing may be accomplished by varying the potential difference between two coaxial cylinders or by employing magnetic focusing. After leaving the accelerating anodes and the deflection means, the deflected particles are allowed to drift in the vertical plane. A high voltage pulse of short duration is applied between the projection plate and grid, and the electrons are accelerated at all points in a plane transverse to the vertical. They pass through the projection grid and strike the fluorescent screen with a velocity proportional to the horizontal projection voltage. The time-space plot of the drifting particles is a diverging plot, but has the characteristic of the applied deflection voltage.

The projection voltage is a periodic function of time. The pulse rises to a maximum value in a very short interval. Its pulse recurrence frequency is much lower than that of the input frequency.

The invention may be used as a wave meter. Assuming that a single cycle, or any multiple thereof, of the periodic vertical deflection voltage is shown on the screen, the frequency may be calculated from the equation:

$$f = \frac{V_0}{L}$$

where f =frequency, V_0 =velocity of electrons entering vertical deflection plates, and L =length of fluorescent screen. The velocity V_0 may be readily determined from the accelerating voltage and is given by:

$$V_0 = \sqrt{\frac{2Ve}{m}}$$

where: $\frac{e}{m}$ =ratio of charge to mass of electron

and V =potential difference between the cathode and the accelerating anode.

In a practical application, a volt-meter indicating the second anode voltage may be calibrated directly in terms of frequency.

The invention may be used not only to examine a wave of very high frequency, but also to examine pulses, for example, square waves, saw tooth waves, pips, etc. In such case the synchronizing problem is facilitated, and furthermore the wave may be examined with considerable spread along the screen, the spread depending upon the velocity of the electrons as determined by acceleration at the gun.

Still another use is to examine the high frequency wave from a magnetron in which the pulse which starts the magnetron may be used to control the projection of the wave against the screen. In this way the shape and growth of the first few cycles each time the magnetron starts may be examined.

Another use of the invention is to examine the merit and particularly the focusing of an electron gun, being designed perhaps for use in ordinary cathode ray tubes. This may be done by building the gun into one of the present tubes, and then projecting the beam laterally against the screen,

This will show the focusing of the beam, including its cross over point, and by changing the focus controls, one can examine the response or movement of the cross over point.

Still another possibility is to examine the bunching of electrons in a velocity modulated tube, by placing the screen of the present invention between spaced apart pairs of grids, and projecting the pulsed electrons laterally against the screen so as to examine the bunched pattern. Or a single externally excited reentrant cavity may be substituted for the deflection plates 16 to velocity modulate the electrons.

Altho the interrupter means 28 is here shown as a trough which traps the beam, it will be understood that other interrupter means may be used. For example, an intensity grid back at the gun may be given a high negative potential, at the same time that the projection plate and grid are pulsed, thus cutting off the beam.

It may be mentioned that although a square pulse is shown in Fig. 3 for projection purposes, it is not essential that the pulse be very short, or very square. So long as the deflected beam moves parallel to itself until it strikes the screen, and so long as the shape of the projection pulse repeats itself cyclically, so that the images on the screen will be superposed, the shape of the projection pulse is relatively unimportant.

The invention herein described may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

It will accordingly be apparent that while we have shown and described our invention in a preferred form, changes may be made without departing from the spirit of the invention, as sought to be defined in the following claims.

We claim:

1. In the operation of the cathode ray tube including an electron gun and a fluorescent screen disposed parallel to the axis of the gun, the method of examining a wave form which includes accelerating electrons to form a beam extending generally parallel to and disposed somewhat behind the screen, and intermittently projecting a substantial length of the deflected beam laterally against the screen for observation.

2. In the operation of a cathode ray tube including an electron gun and a fluorescent screen disposed parallel to the axis of the gun, the method of examining a wave form which includes accelerating electrons to form a beam extending generally parallel to and disposed somewhat behind the screen, deflecting the beam in a plane parallel to the screen in accordance with the wave form to be examined, and intermittently projecting a substantial length of the deflected beam laterally against the screen for observation.

3. In the operation of a cathode ray tube including an electron gun and a fluorescent screen disposed parallel to the axis of the gun, the method of examining a wave form which includes accelerating electrons to form a beam extending generally parallel to the screen in accordance with the wave form to be examined, intermittently projecting a substantial length of the deflected beam laterally against the screen for observation, and at the same time cutting off any additional flow of electrons from the gun to the screen.

4. In the operation of a cathode ray tube including an electron gun and a flat fluorescent screen disposed parallel to the axis of the gun, the method of examining a wave form which includes

accelerating electrons to form a beam extending generally parallel to and disposed somewhat behind the screen, deflecting the beam in a plane parallel to the screen in accordance with the wave form to be examined, intermittently projecting a substantial length of the deflected beam laterally against the screen for observation, and at the same time cutting off any additional flow of electrons from the gun to the screen, the lateral projection of the beam for observation being in synchronism with a sub-multiple of the frequency of the wave form being examined, so that the successive wave forms projected on the screen will be superposed or in registration, in order to form a continuous picture.

5. A cathode ray tube comprising an evacuated envelope, an electron gun, a generally flat fluorescent screen disposed generally parallel to, but offset somewhat from the axis of the gun, deflection means for deflecting the beam in a plane generally parallel to the screen, and projection means to project a substantial length of the deflected beam laterally against the screen for observation.

6. A cathode ray tube comprising an evacuated envelope, an electron gun, a generally flat fluorescent screen disposed generally parallel to, but offset somewhat from the axis of the gun, and projection means including a flat extensive plate or electrode on one side of the beam generally parallel to the screen, and a perforate or grid-like electrode on the other side of the beam and the screen and disposed generally parallel to the screen.

7. A cathode ray tube comprising an evacuated envelope, an electron gun, a generally flat fluorescent screen disposed generally parallel to, but offset somewhat from the axis of the gun, deflection means for deflecting the beam in a plane generally parallel to the screen, and projection means including a flat extensive plate or electrode on one side of the beam generally parallel to the screen, and a perforate or grid-like electrode on the other side of the beam between the beam and the screen and disposed generally parallel to the screen.

8. A cathode ray tube comprising an evacuated envelope, an electron gun, a generally flat fluorescent screen disposed generally parallel to, but offset somewhat from the axis of the gun, focusing means for the electron beam from the gun, deflection means for deflecting the beam in a plane generally parallel to the screen, projection means including a flat extensive plate or electrode on one side of the beam generally parallel to the screen, and a perforate or grid-like electrode on the other side of the beam between the beam and the screen and disposed generally parallel to the screen, and means to interrupt the beam when desired at a point between the gun and the screen.

9. A cathode ray tube comprising an evacuated envelope, an electron gun, a generally flat fluorescent screen disposed generally parallel to, but offset somewhat from the axis of the gun, focusing means for the electron beam from the gun, deflection means for deflecting the beam in a plane generally parallel to the screen, projection means including a flat extensive plate or electrode on one side of the beam generally parallel to the screen, and a perforate or grid-like electrode on the other side of the beam between the beam and the screen and disposed generally parallel to the screen, means to interrupt the beam when desired at a point between the gun and the

screen, and a collector beyond the screen for collecting any residual electrons which pass by the screen without being projected thereon by the projection means.

10. Apparatus for examining a wave form, said apparatus comprising a cathode ray tube including an evacuated glass envelope having a neck-like portion at one end and a flat screen portion at the other end disposed in the direction of the axis of the neck portion, an electron gun in the neck, deflection means at the neck for deflecting the beam in a plane generally parallel to the screen portion, a fluorescent screen on one face of the screen portion, and projection means including a flat plate or electrode on the opposite face of the screen portion and a grid-like electrode disposed parallel to and near the screen, so that the electron beam normally lies between the plate and the grid.

11. Apparatus for examining a wave form, said apparatus comprising a cathode ray tube including an evacuated glass envelope having neck-like portion at one end and a flat screen portion at the other end disposed in the direction of the axis of the neck portion, an electron gun in the neck, beam focusing means at the neck, a fluorescent screen on one face of the screen portion, projection means including a flat plate or electrode on the opposite face of the screen portion and a grid-like electrode disposed parallel to and near the screen, so that the electron beam normally lies between the plate and the grid, and an interrupter at the end of the screen portion nearest the gun and so disposed as to miss the beam except when the beam is projected laterally toward the screen by the projection means.

12. Apparatus for examining a wave form, said apparatus comprising a cathode ray tube including an evacuated glass envelope having a neck-like portion at one end and a flat screen portion at the other end disposed in the direction of the axis of the neck portion, an electron gun in the neck, beam focusing means at the neck, deflection means at the neck for deflecting the beam in a plane generally parallel to the screen portion, a fluorescent screen on one face of the screen portion, projection means including a flat plate or electrode on the opposite face of the screen portion and a grid-like electrode disposed parallel to and near the screen, so that the electron beam normally lies between the plate and the grid, a collector at the extreme end of the screen portion, and an interrupter at the opposite end of the screen portion and so disposed as to miss the beam except when the beam is projected laterally toward the screen by the projection means.

13. Apparatus for examining a wave form, said apparatus comprising a cathode ray tube including an evacuated glass envelope having a neck-like portion at one end and a flat screen portion at the other end disposed in the direction of the axis of the neck portion, an electron gun in the neck, deflection means at the neck for deflecting the beam in a plane generally parallel to the screen portion, a fluorescent screen on one face of the screen por-

tion, projection means including a flat plate or electrode on the opposite face of the screen portion and a grid-like electrode disposed parallel to and near the screen, so that the electron beam normally lies between the plate and the grid, a collector at the extreme end of the screen portion, an interrupter at the opposite end of the screen portion and so disposed as to miss the beam except when the beam is projected laterally toward the screen by the projection means, a pulse generator connected to the projection means, and means for applying the wave form to be examined to the deflection means.

14. Apparatus for examining a wave form, said apparatus comprising a cathode ray tube including an evacuated glass envelope having a neck-like portion at one end and a flat screen portion at the other end disposed in the direction of the axis of the neck portion, an electron gun in the neck, beam focusing means at the neck, deflection means at the neck for deflecting the beam in a plane generally parallel to the screen portion, a fluorescent screen on one face of the screen portion, projection means including a flat plate or electrode on the opposite face of the screen portion and a grid-like electrode disposed parallel to and near the screen, so that the electron beam normally lies between the plate and the grid, a collector at the extreme end of the screen portion, an interrupter at the opposite end of the screen portion and so disposed as to miss the beam except when the beam is projected laterally toward the screen by the projection means, a pulse generator connected to the projection means, means for applying the wave form to be examined to the deflection means, and means to establish a sub-multiple synchronous relation between the wave form being examined and the pulse generator.

15. A cathode ray tube, as defined in claim 7 in which the deflecting means consists of deflection plates disposed perpendicular to the plane of the screen.

16. A cathode ray tube, as defined in claim 7 in which the deflecting means consists of a resonant transmission line or Lecher wires.

17. A cathode ray tube, as defined in claim 7 in which the deflecting means consists of a resonant cavity built into or around the neck of the tube.

18. A cathode ray tube in which the deflecting means consists of a resonant cavity built into or around the neck of the tube.

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