

March 7, 1961

J. E. LINDBERG, JR., ET AL
SECONDARY-EMISSION CATHODE-RAY TUBE AND
ENGINE ANALYZER EMPLOYING THE SAME

2,974,274

Filed Dec. 13, 1955

8 Sheets-Sheet 1

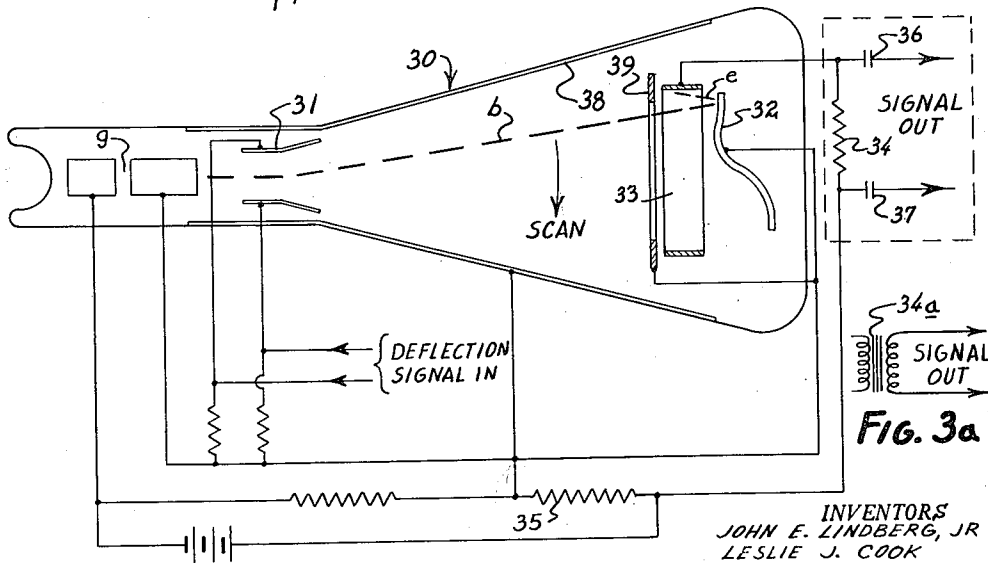
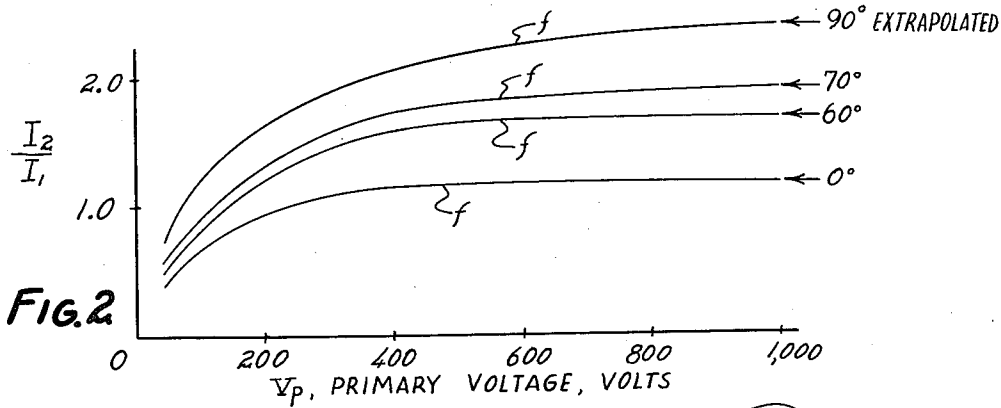
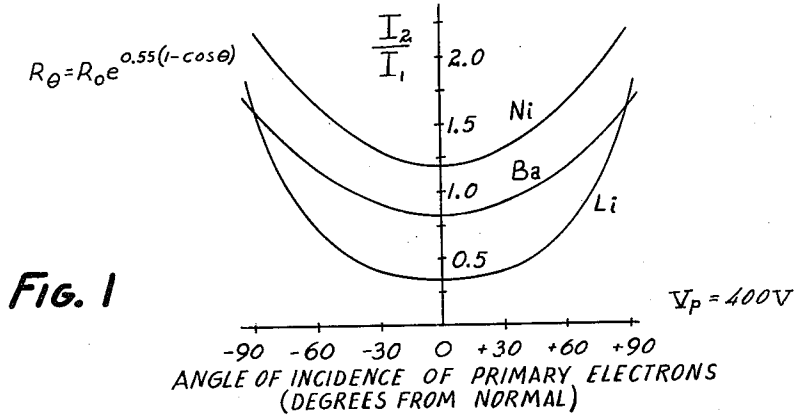


Fig. 3

INVENTORS
JOHN E. LINDBERG, JR.
LESLIE J. COOK
BY
[Signature]
ATTORNEY

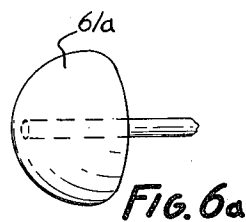
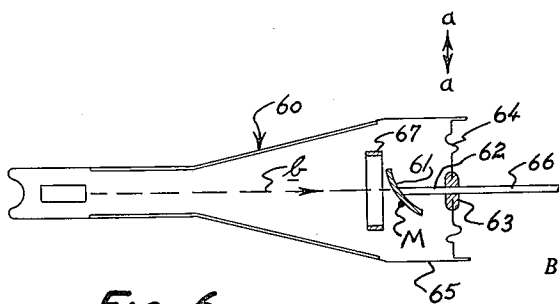
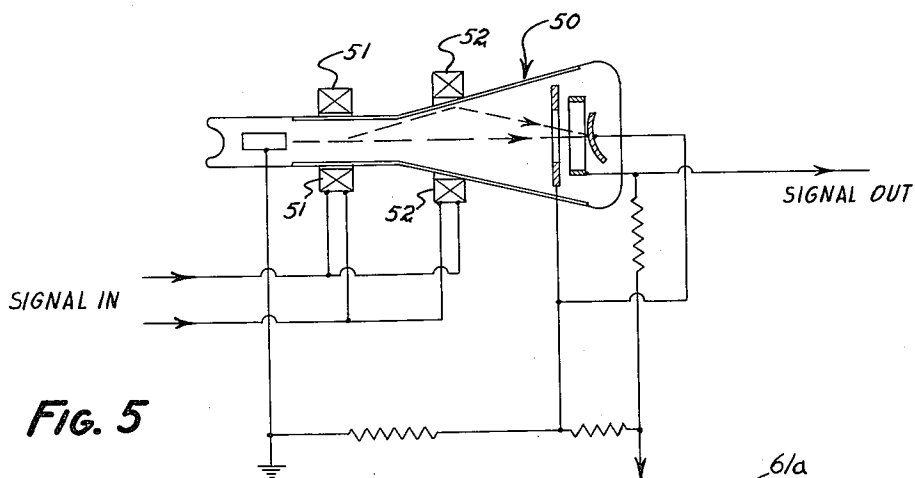
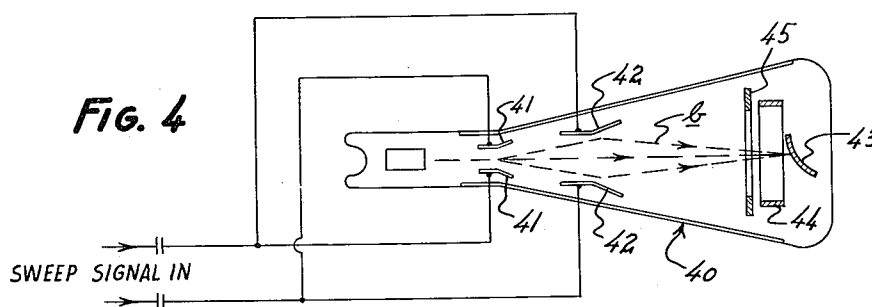
March 7, 1961

J. E. LINDBERG, JR., ET AL
SECONDARY-EMISSION CATHODE-RAY TUBE AND
ENGINE ANALYZER EMPLOYING THE SAME

2,974,274

Filed Dec. 13, 1955

8 Sheets-Sheet 2



INVENTORS
JOHN E. LINDBERG, JR.
LESLIE J. COOK

BY

A. D. Hansen
ATTORNEY

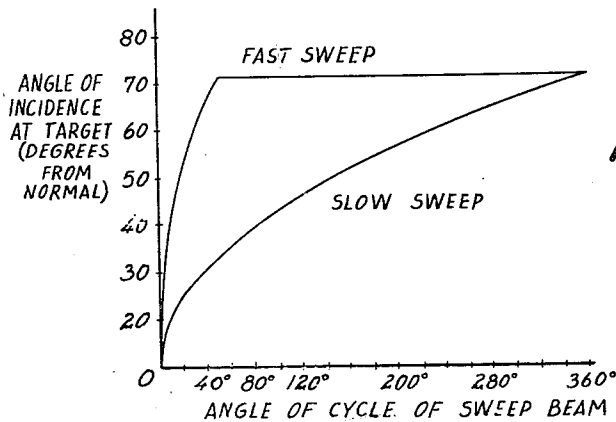
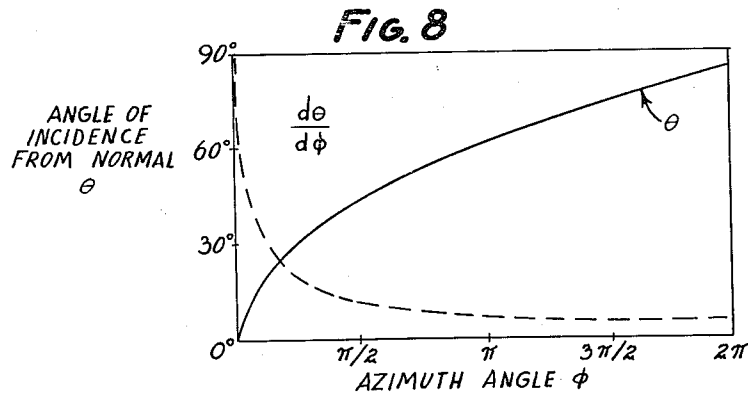
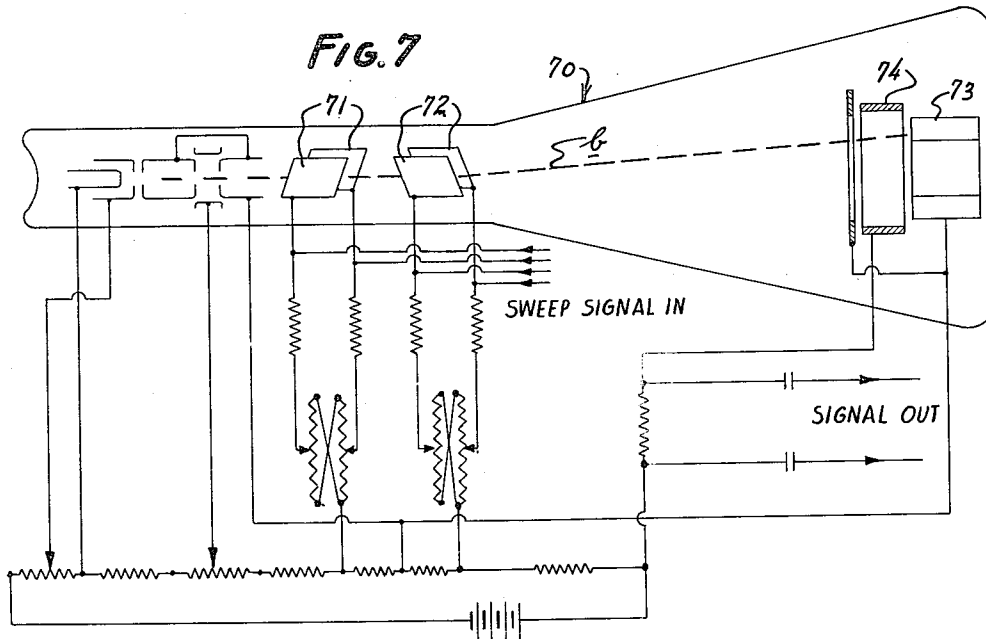
March 7, 1961

J. E. LINDBERG, JR., ET AL
SECONDARY-EMISSION CATHODE-RAY TUBE AND
ENGINE ANALYZER EMPLOYING THE SAME

2,974,274

Filed Dec. 13, 1955

8 Sheets-Sheet 3



INVENTORS
JOHN E. LINDBERG, JR.
LESLIE J. COOK
BY
A. Duhamel
ATTORNEY

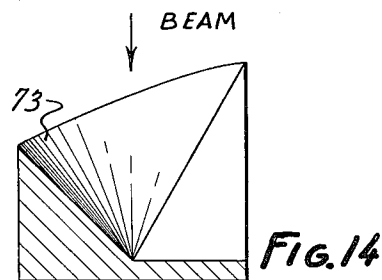
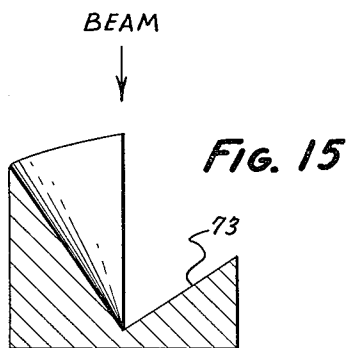
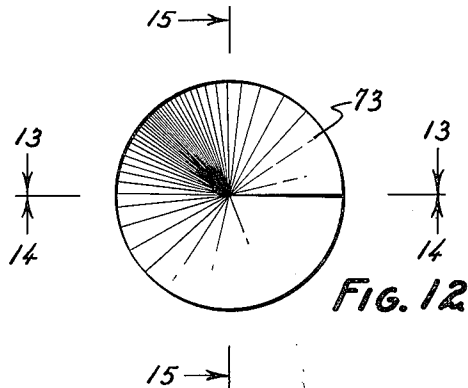
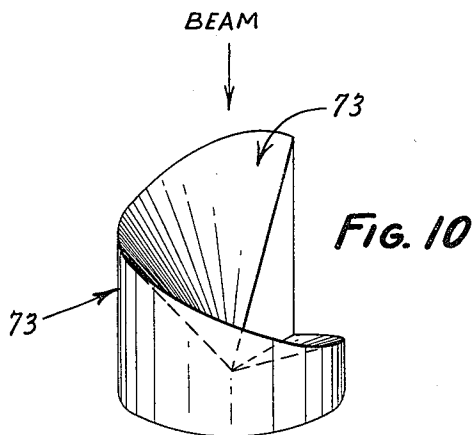
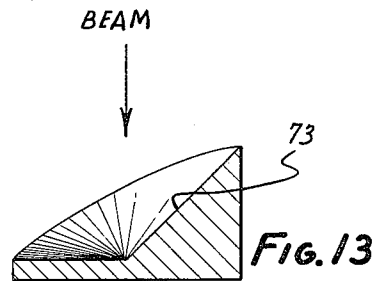
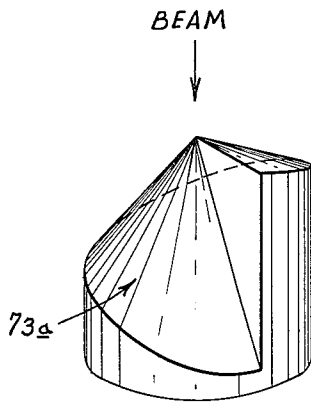
March 7, 1961

J. E. LINDBERG, JR., ET AL
SECONDARY-EMISSION CATHODE-RAY TUBE AND
ENGINE ANALYZER EMPLOYING THE SAME

2,974,274

Filed Dec. 13, 1955

8 Sheets-Sheet 4



INVENTORS
JOHN E. LINDBERG, JR.
LESLIE J. COOK

BY

A. D. ...
ATTORNEY

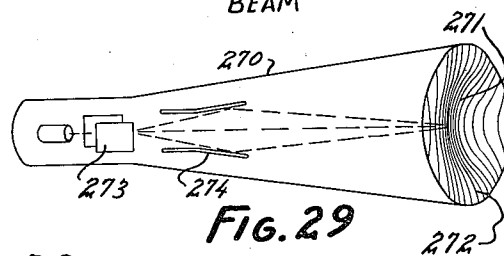
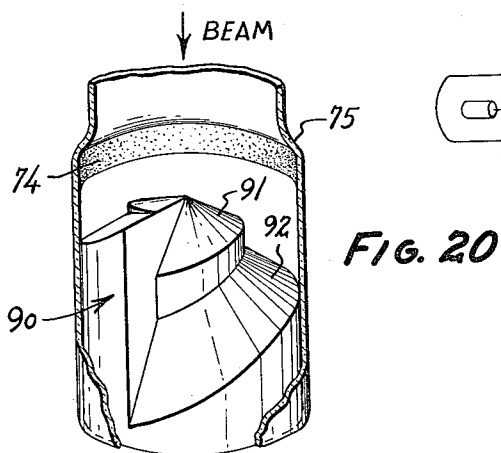
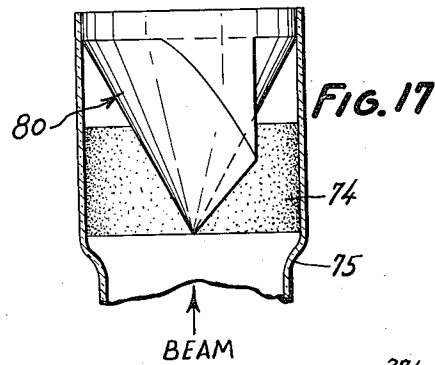
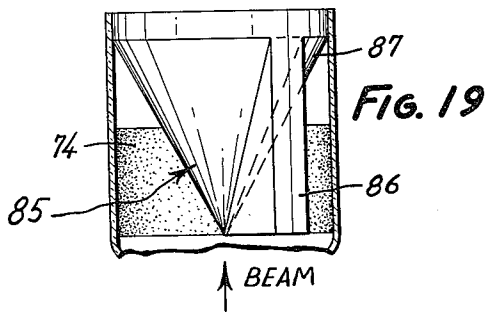
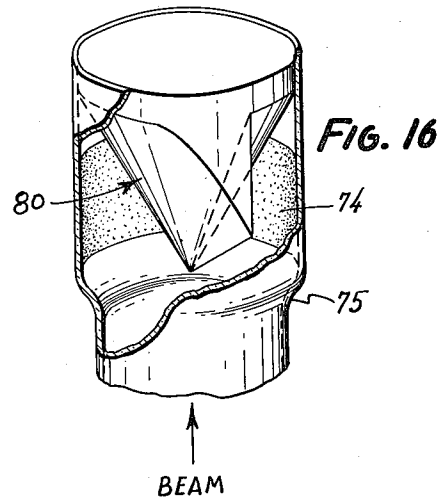
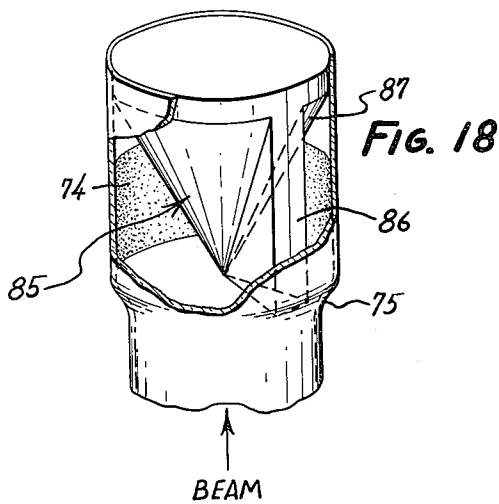
March 7, 1961

J. E. LINDBERG, JR., ET AL
SECONDARY-EMISSION CATHODE-RAY TUBE AND
ENGINE ANALYZER EMPLOYING THE SAME

2,974,274

Filed Dec. 13, 1955

8 Sheets-Sheet 5



INVENTORS
JOHN E. LINDBERG, JR.
LESLIE J. COOK
BY *A. D. Dineen*
ATTORNEY

March 7, 1961

J. E. LINDBERG, JR., ET AL
SECONDARY-EMISSION CATHODE-RAY TUBE AND
ENGINE ANALYZER EMPLOYING THE SAME

2,974,274

Filed Dec. 13, 1955

8 Sheets-Sheet 6

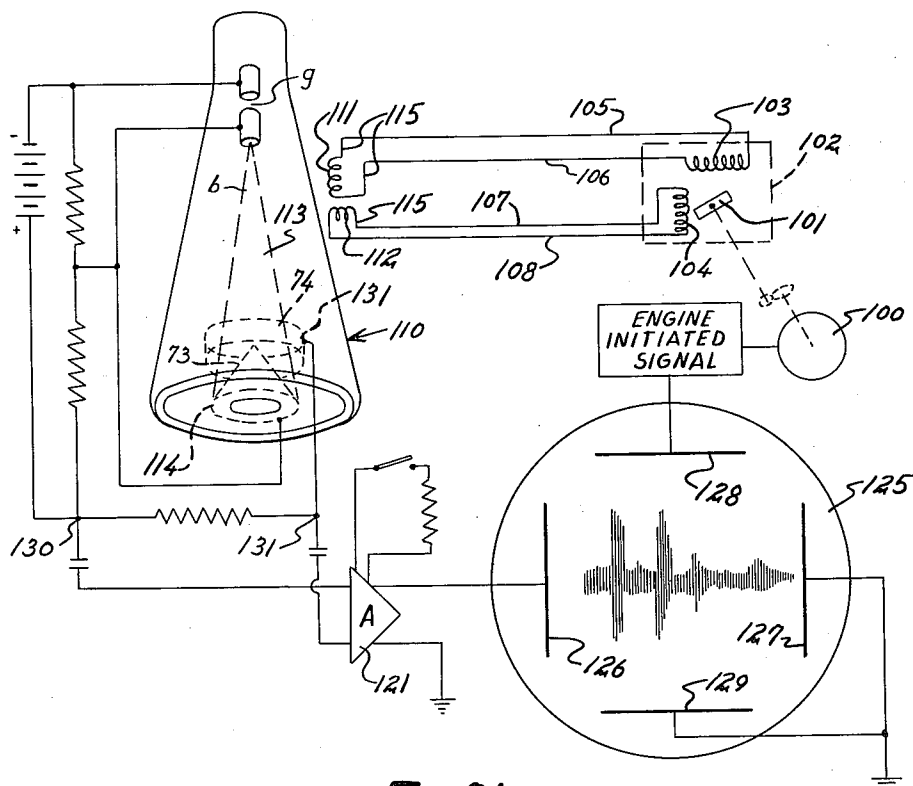


Fig. 21

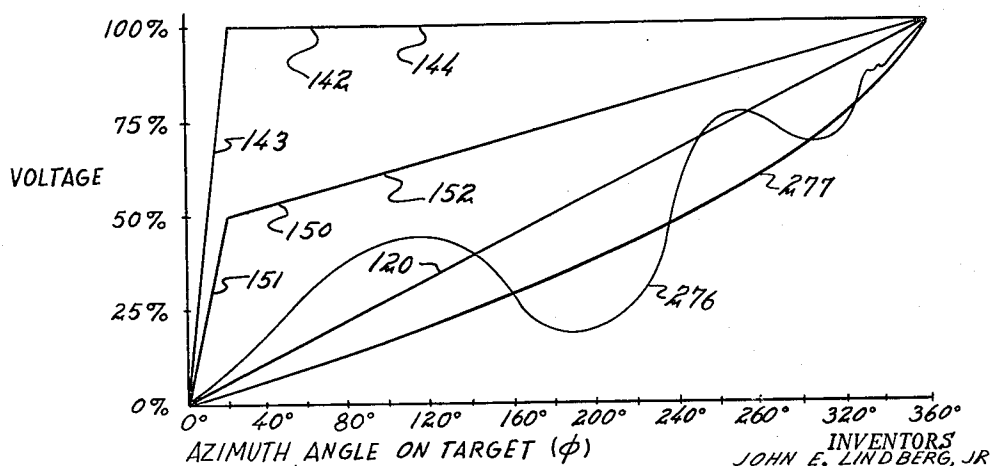


Fig. 22

INVENTORS
JOHN E. LINDBERG, JR.
LESLIE J. COOK
BY
A. D. Inham
ATTORNEY

March 7, 1961

J. E. LINDBERG, JR., ET AL
SECONDARY-EMISSION CATHODE-RAY TUBE AND
ENGINE ANALYZER EMPLOYING THE SAME

2,974,274

Filed Dec. 13, 1955

8 Sheets-Sheet 7

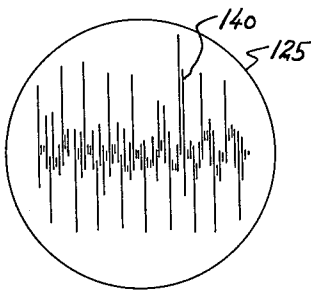


FIG. 23

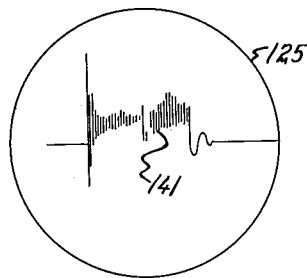


FIG. 24

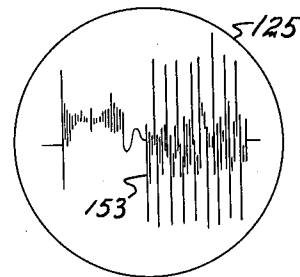


FIG. 25

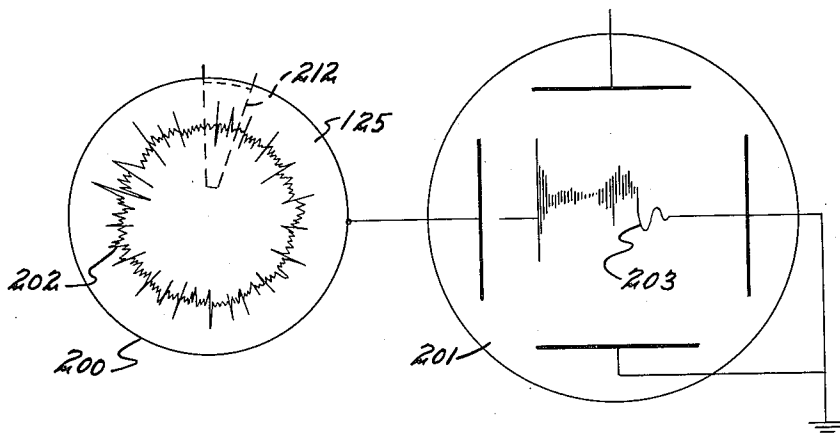


FIG. 27

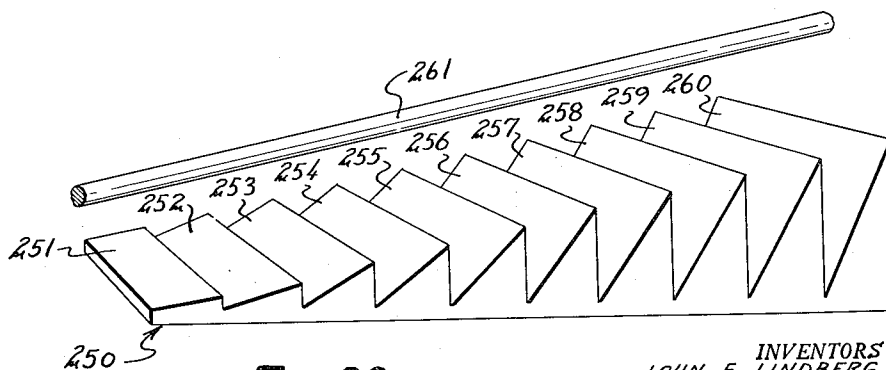


FIG. 28

INVENTORS
JOHN E. LINDBERG, JR.
LESLIE J. COOK

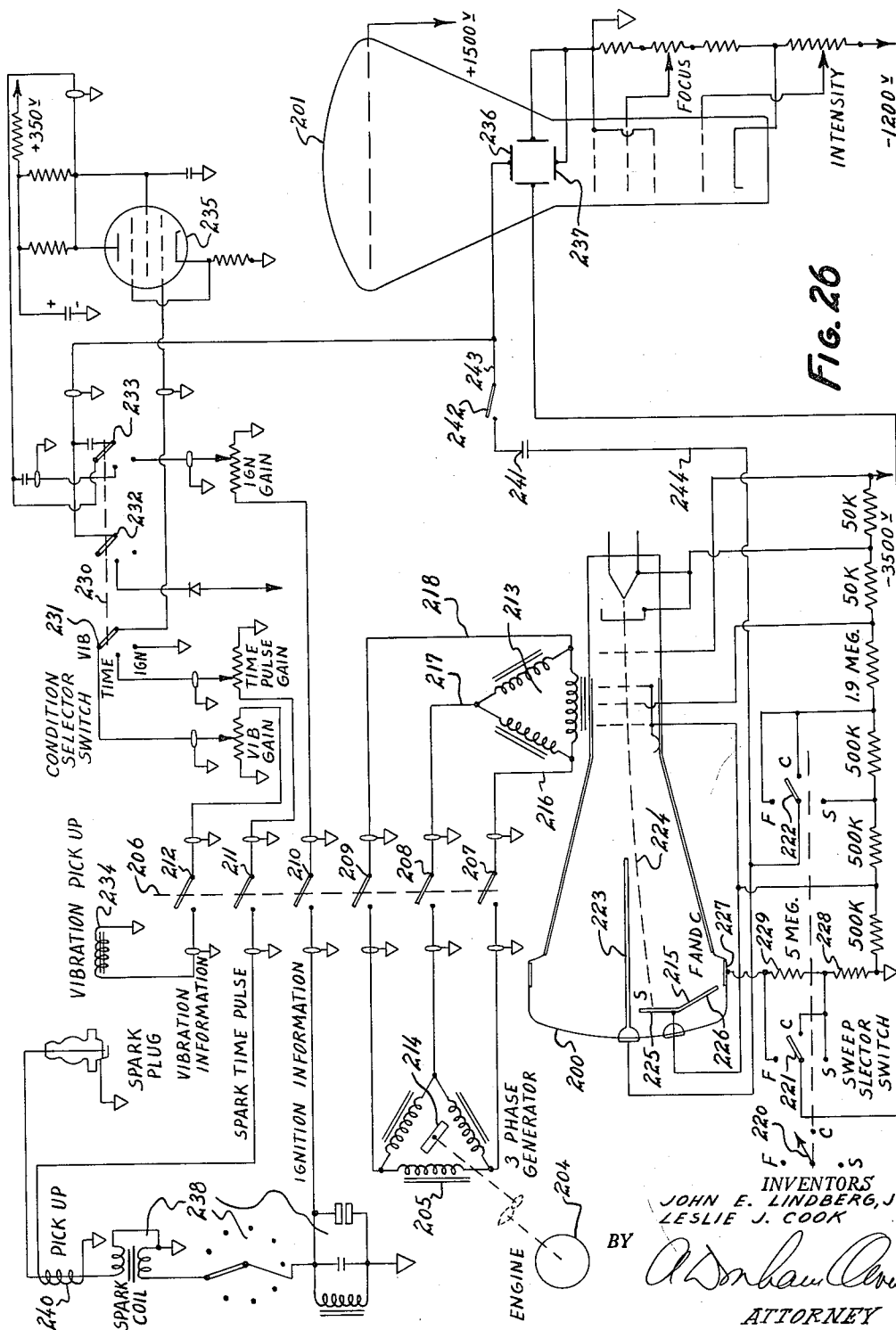
March 7, 1961

J. E. LINDBERG, JR., ET AL
SECONDARY-EMISSION CATHODE-RAY TUBE AND
ENGINE ANALYZER EMPLOYING THE SAME

2,974,274

Filed Dec. 13, 1955

8 Sheets-Sheet 8



1

2,974,274

SECONDARY-EMISSION CATHODE-RAY TUBE AND ENGINE ANALYZER EMPLOYING THE SAME

John E. Lindberg, Jr., 1170 Oleander Drive, and Leslie J. Cook, both of Lafayette, Calif.; said Cook assignor to said Lindberg

Filed Dec. 13, 1955, Ser. No. 552,870

16 Claims. (Cl. 324—16)

This invention relates to a novel type of cathode-ray tube utilizing the phenomenon of secondary electron emission. The invention also relates to an improved engine analyzer, and particularly to a positively synchronized sweep circuit for an engine analyzer, incorporating therein an auxiliary cathode-ray tube having a target which emits secondary electrons that are collected and form the basis of the sweep circuit for a main cathode-ray tube.

The phenomenon of secondary emission

When an electron or other electrically charged particle strikes a surface, it may, under certain conditions, give rise to the emission from that surface of one or more electrons. The released electrons are conventionally termed "secondary electrons," and the phenomenon is therefore called "secondary emission." An explanation of this phenomenon will be found in such works as the articles by Bruining and De Boer on secondary emission in *Physica*, January 1938 through October 1939, and *Techniques in Experimental Electronics* by C. H. Bachman, published in 1948 by John Wiley & Sons, Inc., New York. Mr. Bachman deals with secondary electron emission in a section that begins on page 164, where he says:

"These secondary electrons are emitted in random directions, and with all velocities up to that of the incident electron beam. Most of the secondaries, however, will be found to possess velocities of only a few volts.

"The number emitted per primary electron varies with the character of the surface and the velocity and angle of incidence of the primary electron.

"Secondary emission as a practical source of electrons presents the basic consideration that one high energy electron can be made to generate a number of lower energy electrons. This attribute makes it attractive as a current amplifier. Multiplier tubes of many designs have been built for this application."

A chapter on the "multiplier photo tube" appears in *Photoelectricity and Its Application* by V. K. Zworykin and E. G. Ramberg, copyright 1949 by John Wiley & Sons, Inc. This chapter is based upon the above mentioned behavior of secondary-emission electrons, and the yield curves for many metals are given therein.

The following excerpt is from page 136:

"The average number of secondary electrons . . . depends strongly both on the nature of the solid and on the energy of the incident electrons. On the other hand, the velocity and angular distribution of the secondary electrons is only slightly dependent on the primary energy and varies little from substance to substance. The energy distribution has, in general, a rather pronounced maximum in the range between 1.4 and 2.2 electron volts—and is quite narrow for the familiar photoemitters. The distribution in angle, like that of photoelectrons, obeys the cosine law."

It is an object of our invention to utilize secondary emission in a novel structure that achieves new and

2

different results by providing relative angular movement between an electron beam and a target and to vary the angle of incidence of the primary electrons in relation to selected conditions. The result is to vary the secondary emission of electrons from the target according to a predetermined pattern. For example, in one application we cause an electron beam in a cathode-ray tube to describe a circular path upon a target constructed so as to vary the angle of incidence at a rate that causes a linear variation in secondary emission with angle of sweep; as a result a sawtooth wave is produced that can be used as a sawtooth sweep for another cathode-ray tube. Similarly, practically any other wave form can be produced.

Another object of the invention is to provide many types of combinations of secondary emission with relative movement between a target and an electron beam, during which relative movement the angle of incidence of the electron beam is varied.

Synchronization of engine analyzers

Engine analyzers, such as the one illustrated in the John E. Lindberg, Jr., Patent #2,518,427, are used to investigate the performance of engines while they are in actual operation. Selected signals from any of various parts of the engine may be impressed across one set of deflection plates in a cathode-ray oscilloscope, and a sweep signal is impressed across the other set of deflection plates. The result is a pattern that, when studied, indicates the performance of the engine.

Synchronization of the sweep circuit with the engine signal circuit has been a very difficult problem. Heretofore, oscilloscope sweeps have been generated independently of the engine by charging and discharging a condenser or by some other means that varies the voltage at a uniform rate over a predetermined period of time, so as to change the voltage differential between the cathode-ray deflection plates uniformly with time. But this type of sweep circuit has been unable to cope successfully with the synchronization problem, because an engine necessarily operates at different speeds, which vary tremendously. Whenever the engine speed changed, the sweep circuit tended to lengthen or shorten the diagram, and measurement of absolute lengths along the diagram became meaningless, since the lengths could not be related directly to engine conditions.

The prior art sought to solve this problem by providing, in various ways, compensation from an engine-initiated pulse. A typical compensator is shown in the E. F. Weller, Jr., et al. Patent #2,645,715. There, the charging rate of the sweep-generating condenser is regulated by a circuit which is controlled by pulses from the engine, to provide a constant amplitude sweep circuit. In other words, the independent sweep circuit was modified in the attempt to synchronize the voltage change with the engine speed. The modifying circuit for this compensating apparatus was very complex; the one referred to in E. F. Weller, Jr., et al. Patent #2,645,715 utilized six electronic tubes plus a mechanical circuit breaker. The best circuit currently in use is even more complex, and includes eleven electronic tubes. This reliance on compensators has left synchronization a difficult and expensive problem; special items of equipment, such as special generators, have been required; and the results have still not been completely satisfactory, especially during periods of acceleration and deceleration in the engine being studied.

We have solved these problems by a new approach to the sweep circuit. Our invention obtains its sweep circuit synchronization directly from the engine being analyzed. Our new sweep is always necessarily in phase with the engine signal, and synchronization of the sweep

with the engine cycle is completely unaffected by changes in speed.

In addition to achieving the object of perfect synchronization, our sweep circuit has other remarkable features; it can use a standard type of generator which may already be on the engine, and contains no other moving parts. It makes it possible to time the initiation of the sweep directly in the cabin of the plane instead of having to make adjustments in the engine. In addition, as will appear, the engine provides a sweep circuit of great versatility; the type of sweep can be varied for different kinds of analyses simply by throwing a switch which changes circuit impedance.

In brief, our invention contemplates obtaining the basic sweep signal from a generator driven by the engine and running at engine cycle speed. In a typical example, two currents ninety degrees out of phase are obtained from the single generator, and these are impressed upon the two pairs of deflection plates of an auxiliary cathode-ray tube so as to give a circular sweep. This signal—an electron beam swept in a circle—impinges on a target constructed with its surface presenting different angles of incidence to the beam. The resultant secondary electrons are collected to produce a sawtooth (or other type) of voltage which, properly amplified if necessary, can then be impressed across the sweep plates of the main cathode-ray tube of the engine analyzer itself. Basically, then, the analyzer invention operates by first using an engine to generate a circular sweep. This signal—an electron beam swept in a circle—impinges in a target constructed with its surface presenting different angles of incidence to the beam. The resultant secondary electrons are collected to produce a sawtooth (or other type) of voltage which, properly amplified if necessary, can then be impressed across the sweep plates of the main cathode-ray tube of the engine analyzer itself. To summarize, the analyzer invention operates by first using an engine to generate a circular sweep of electrons whose cycle therefore depends directly on the engine cycle; this circularly swept electron beam is then used in combination with the novel target to produce a varying electric voltage suitable for control of the engine analyzer sweep circuit.

Other features, objects, and advantages of the invention will become apparent from the following description presented in accordance with 35 U.S.C. 112.

Fig. 1 is a typical series of curves for three target materials plotting angle of incidence of primary electrons against the emission ratio of secondary electrons to primary electrons.

Fig. 2 is a graph of typical empirical data and some extrapolated curves plotting the primary voltage against the current ratio of secondary to primary electron flow emitted from a nickel target at several different angles.

Fig. 3 is a simple circuit diagram of a cathode-ray tube embodying the principles of our invention, in which a sweep signal is impressed on an electron beam which scans across a target electrode of irregular configuration so as to present at each point a different angle of incidence.

Fig. 3a is a fragmentary view of a modified portion of the circuit of Fig. 3.

Fig. 4 is a simplified diagram of a modified form of cathode-ray tube employing double electrostatic deflection.

Fig. 5 is a simplified diagram of another tube like that of Fig. 4, but employing magnetic deflection.

Fig. 6 is a simplified diagram of a cathode-ray tube having a mechanically moved transducer probe whose target electrode is moved while the electron beam remains stationary, to vary the angle of incidence of the electron beam and thereby vary the secondary emission ratio.

Fig. 6a is a fragmentary view of a modified type of target for use in Fig. 6.

Fig. 7 is a circuit diagram of a cathode-ray tube capa-

ble of use in an engine analyzer to produce a sawtooth voltage.

Fig. 8 is a graph showing the plotting of the angle of incidence from normal against the azimuth angle for a 360° target that will provide a sawtooth sweep.

Fig. 9 is a graph like Fig. 8 showing the plotting of both a slow sweep target and a fast sweep target.

Fig. 10 is a greatly enlarged view in perspective of a target to provide a 360° sawtooth sweep, which can be used as a slow (complete engine cycle) sweep in an engine analyzer.

Fig. 11 is a view similar to Fig. 10 of a similar target in which the surface presented to the beam is inverted.

Fig. 12 is a top plan view of the target of Fig. 10.

Figs. 13, 14 and 15 are sectional elevation views of the target of Fig. 10, taken respectively, along the lines 13—13, 14—14, and 15—15 in Fig. 12.

Fig. 16 is an enlarged view in perspective of a target adapted to provide a fast sweep (selected small portion of complete engine cycle).

Fig. 17 is a view in side elevation of the target of Fig. 16.

Fig. 18 is a view in perspective of a target adapted to produce a square wave.

Fig. 19 is a view in side elevation of the target of Fig. 18.

Fig. 20 is a view in perspective of a composite target adapted to provide either slow or fast composite sweep depending on whether the beam which is swept in a circle is moved at a larger or smaller radius.

Fig. 21 is a diagrammatic representation of an engine analyzer and a simple circuit therefor embodying the principles of our invention. Here, magnetic deflection coils are used in place of electrostatic deflection plates, though either type of deflection system may be used.

Fig. 22 is a diagram, plotting angle against percent of full sweep voltage for each of several targets shown in Figs. 10—19, and corresponding to the final sweep curve for each element.

Fig. 23 is an illustration of one type of engine analyzer pattern, obtained from a signal initiated by the engine and from the sweep given by the element of Fig. 10.

Fig. 24 is an illustration of a pattern obtained from the same engine signal as that of Fig. 23 but using the sweep given by the element of Fig. 16.

Fig. 25 is an illustration of a pattern obtained from the same engine signal as Figs. 23 and 24, using the element of Fig. 20 to obtain the sweep.

Fig. 26 is a circuit diagram of a modified form of engine analyzer.

Fig. 27 is a front elevation view of the two cathode-ray tubes of Fig. 26 seen head on and side by side.

Fig. 28 is a view in perspective of another novel form of target useful in a digital computer.

Fig. 29 is a diagram showing the use of another modified type of target.

Secondary emission varies with the angle of incidence of the primary beam

When primary electrons strike a surface, secondary electrons are emitted at all angles, following a cosine law of distribution. As the angle of incidence (from normal, denominated 0° of incidence) of the primary electrons is varied, the secondary-to-primary-emission ratio increases as the primary electrons strike less perpendicularly and more nearly parallel to the surface. The increase in secondary emission with angle is believed primarily due to the fact that as the angle of incidence becomes more nearly grazing, the primary electrons exchange their energy with the target in layers nearer to the surface. Furthermore, since they have components of velocity parallel to the surface, they can exchange energy elastically with free electrons in the target as well as with valence electrons.

Fig. 1 illustrates this effect. The secondary emission

curves at 400 volts for nickel, barium and lithium are shown, plotting the angle of incidence of the primary electrons against the resultant ratio of secondary electron current to primary electron current

$$\left(\frac{I_2}{I_1}\right)$$

It will be noted that for lithium the secondary electron emission does not reach equality with the primary electron bombardment until the angle of incidence reaches about 75° from normal. For barium, equivalency is reached much sooner, around 45°, but the curve is flatter. For nickel, the ratio, even at 0°, is about 1.2, and the ratio increases according to the cosine law to a ratio of about 2.2 at plus 90° and minus 90° from normal. Thus, it is seen that the selection of the material is important, but that no matter what material is selected, there will be a considerable difference in secondary-electron emission, depending on the angle of incidence of the primary electron beam.

In the light of the foregoing explanation, a cathode-ray tube provided with a circular sweep, where the target is flat and approximately normal to the axis of the electron beam, the movement of the beam will not produce any change in secondary-electron emission.

In our invention, however, the target itself is so formed as to vary this angle of incidence, and the rate of secondary emission will change with the angular position of the circular beam. It should be noted, however, that if the rate of change is constant, that is, if the change in slope (second derivative) is constant from, say, a 0° angle of incidence (from normal) to a 90° angle, a sawtooth curve will not result. This point will be explained below.

Effect of surface composition

The secondary primary emission ratio depends on the composition of the surface, as Fig. 1 shows. It varies over a considerable range with pure metals and is almost an order of magnitude larger with certain composite surfaces. However, there are no systematic rules for the classification. In fact, contrary to normal expectation, there are several cases in which an enhanced secondary emission ratio is associated with increase in work-function.

Typical values of maximum secondary emission ratio at normal incidence follow:

Tungsten	1.4	Lithium fluoride	5.6
Copper	1.3	Potassium chloride	7.5
Nickel	1.3	Sodium chloride	6.8
Iron	1.25	Sodium fluoride	5.7

Effect of changes in primary voltage

Fig. 2 illustrates the effect of primary voltage on the ratio of secondary to primary electron current at several different angles on the same material, that is, nickel. This illustrates the fact that the selection of the primary voltage can have an important effect and that for consistent results the voltage should be high enough to intersect the relatively flat portions *f* of the curves. This is also the place where the change due to an angle is most marked, as will be seen by the distances between the curves illustrated in Fig. 2. This figure also shows that once this relatively flat portion *f* of the curves is reached, a further increase in voltage would waste energy, since hardly any difference in ratio results.

A linear scanning device utilizing a stationary target with surface changes affecting the angle of incidence of the electron beam

One general embodiment of this invention is shown schematically in Fig. 3 in the cathode-ray tube 30. An electron beam *b* is produced by a standard type electron gun *g* and is caused to deflect vertically, as, for example, by a sawtooth sweep impressed to execute a scan pattern

by the action of the deflection plates 31. This beam *b* impinges on a target 32 which is formed in some predetermined pattern and causes secondary electrons *e* to be emitted. The primary electron beam *b* may be constant in magnitude but because of the variation in angle of incidence with the target 32 as it scans across the target 32, the magnitude of the secondary electron current will have a time and position-wise variation. The exact nature of this variation depends on the contour of the target electrode 32 and on the relation given above for the variation in secondary-primary ratio with angle of incidence. The secondary electrons *e* are collected by a collector ring 33 and a corresponding current flows through a load resistor 34 to the positive side of the power supply bleeder 35. The voltage generated across this load resistor constitutes the desired signal which is then coupled to the receiving device through the coupling capacitors 36, 37. A bulb wall coating 38 of colloidal graphite ("Aquadag") prevents stray charges. A shield 39 prevents primary electrons from striking the collecting electrode 33.

The operation of the Fig. 3 diagram is predicated upon having the electron beam *b* scan the target 32 vertically. The surface of the target electrode 32 presents a different angle of incidence at every position of the travel of the beam *b*. The upper end of the surface is approximately flat; it turns convexly in a fairly sharp curve, and then becomes flatter again at its lower end. As a result, the beam *b* first strikes at practically normal angle of incidence, approaching 0°, and therefore the ratio of secondary emission will be at or near the minimum. As the beam moves across the sharp curve, the ratio increases. Then, as the curve flattens again, the ratio drops. Such a beam can therefore be used to produce, with amplification, a sweep signal output which will vary from a low amount to a high amount and back to the low amount. Similarly, any other pre-selected wave form may be obtained by proper target configuration. The target 32 may be the end of the tube 30, and, by the use of the second deflector perpendicular to the deflector 31, the whole area of the target 32 may be employed.

This example illustrates the fact that the current output from the target-32-collector-ring-33 combination is ordinarily used to develop a voltage across a load and is then coupled to the device to be driven. This coupling may be capacitive, as shown, through the condensers 36 and 37, or it may be direct, by omitting either or both condensers 36 and 37, or it may through the electromagnetic field as illustrated in Fig. 3a. There, a transformer 34a is adapted so that one side serves as the load, and the other is connected to the device to be driven, using the signal put out by the tube 30. If isolation is not desired, the output may be taken across the input coil of the transformer 34a, or a simple coil may replace the transformer 34a, as for a frequency-sensitive device. As a further alternative, a magnetic amplifier may be used in place of the transformer 34a, and in the same manner. As a further alternative, it is possible and may in some instances be preferable to utilize the current output from the tube 30 directly, in which instances the device to be driven in effect replaces the load 34. Generally speaking, it is preferable to isolate the tube 30 from the device to be driven, either by the capacitive or inductive couplings just described.

Instead of a sawtooth sweep, any other kind of deflection may be used, depending on the result to be obtained. It need not be periodic deflection, but may merely be a change between two or more static positions.

Double deflection system utilizing a stationary point of incidence with varying angles of incidence due to target configuration

Another form of this invention is shown in Fig. 4. Here, in a cathode-ray tube 40, two successive sets of

deflection plates 41, 41 and 42, 42 are connected in opposition as shown. Thus the deflection of the beam b by the first set 41, 41 is effectively cancelled by the second set 42, 42, and as the sweep signal goes through its cycle the beam b continues to strike the same point on a target 43. However, it will be observed that the position of the virtual source of the beam b varies up and down and thus the angle of incidence of the beam b on the target 43 varies with the signal applied. This together with the relation given above results in a variation in secondary emission collected by the ring 44, and thus in the generation of an electrical signal. The ring 44 is protected from primary electrons by a shield 45. If the target 43 is formed as shown, the point p of impingement of the beam b can be changed by applying a relative bias to one set of plates 41, 41 or 42, 42, and if the direction of the normal to the surface at the point of impingement is changed, the magnitude and/or shape of the generated signal will be changed correspondingly.

The same phenomena are produced in the tube 50 shown in Fig. 5, where magnetic deflection coils 51, 52 replace the deflection plates 41, 41, 42, 42 of the device of Fig. 4. Operation is the same.

Angle of incidence varied by motion of the target

A form of this invention which constitutes a transducer for the conversion of mechanical displacements or motions into electrical signals is shown in Fig. 6. In this case no deflection system is required.

Here, the tube 60 has a target 61 mounted on a cantilever support 62 which extends through an insulator 63 in a diaphragm 64 which constitutes the end wall of the vacuum envelope 65. The extension 66 of the target support 62 serves as a transducer probe. Mechanical forces applied to the probe 66 thus produce radial displacements of the target electrode 61. In this instance an electron gun without deflection plates is used to propel the beam b over a stationary linear path, the secondary emission being varied solely by the motion of the target 61. As in the cases above, an electrical signal is developed in a load resistor through which flows the current collected by a collector ring 67. The target 61 may be a hemisphere as shown in Fig. 6a or it may be asymmetric as shown in Fig. 6, or any desired configuration, and it will be noted that as it undergoes any radial displacement the angle of incidence of the beam b will vary accordingly. This transducer can be used as a vibration pickup. Motion in direction a — a will cause motion of the target 61 relative to the tube 60, due to the mass of the target and to the spring action of the diaphragm 64 or support 62. Motion perpendicular to a — a causes no output when the target 61 is used. However, if the target 61a of Fig. 6a is used, the output will be equal for vibration in any plane perpendicular to the axis of the support 62, but zero in line of that axis. Positioning of a mass M out of line with the axis will result in motion of the target when it is vibrated in the axis.

Cathode ray tube utilizing circular sweep

A preferred tube 70 of this invention is shown in Fig. 7. Here, a sinusoidal signal is applied to the two sets of deflection plates 71, 71 and 72, 72 in quadrature. This results in a circular sweep by the beam b . The target electrode 73 is so constructed that it resembles a spiral with continuously increasing pitch. The exact schedule of this pitch variation may be so determined and controlled that as the primary beam b executes its circular sweep, the secondary current, collected by a collector ring 74 has an accurately sawtooth shape (Figs. 7-11), or other shapes may be devised (Figs. 12-20), shown in the diagram, Fig. 22.

Calculation of slope of the target

The following relation is well established.

$$(1) \quad d\theta = d_0 e^{p(1-\cos \theta)}$$

where:

d_0 = ratio of secondary to primary electrons at angle θ ,
 d_0 = ratio of secondary to primary electrons at angle 0,
 θ = angle of incidence (angle from normal) of the primary electrons,
 p = a coefficient that increases with primary potential.

This relation is utilized in the construction of the target configuration.

The following relations are essentially definitions:

$$(2) \quad d_0 = \frac{i_s}{i_p}$$

where:

i_p = primary beam current, amperes
 i_s = secondary electron current due to a primary beam impinging at normal incidence, amperes.

$$(3) \quad V = Ri_s$$

where:

R = the secondary collector load resistance, in ohms,
 V = the potential developed across the load resistor, in volts; i.e., the output voltage.

This output voltage may also be expressed as

$$(4) \quad V = V_0 + V(W)$$

where:

V_0 = the static output voltage when the primary beam impinges at normal incidence,
 W = a parameter associated with the motion of the beam over the surface, e.g., a distance measured on the surface; or azimuth angle associated with a circular scan.
 $V(W)$ = the varying part of V , expressed as a function of W .

The relations given above may now be combined in the following form:

$$(5) \quad V_0 + V(W) = Ri_p d_0 e^{p(1-\cos \theta)}$$

or, rearranging,

$$(6) \quad \theta = \arccos \left(1 - \frac{1}{p} \ln \frac{V_0 + V(W)}{Ri_p d_0} \right)$$

This relation constitutes a formula for the construction of a surface contour, $\theta = \theta(W)$, in order to generate an electrical wave shape, $V = V(W)$.

Generation of a linear sawtooth wave

In this case we may write,

$$(7) \quad V(W) = aW$$

where a is a constant coefficient. Thus

$$(8) \quad \theta = \arccos \left(1 - \frac{1}{p} \ln \frac{V_0 + aW}{Ri_p d_0} \right)$$

A specific sawtooth generator (see fig. 7)

Now consider the cathode-ray tube 70 wherein the target 73 is annular and the beam b is swept continuously in a circular pattern. The target parameter may be taken as the azimuth angle ϕ and we may take its range as, $0 \leq \phi \leq 2\pi$. The problem, then, is to determine the man-

ner in which θ should vary with azimuth. Assuming for example the following values:

$$\begin{aligned} p &= 0.5 \\ R &= 2 \times 10^8 \text{ ohm} \\ i_p &= 10^{-4} \text{ ampere} \\ d_0 &= 2 \\ a &= 240/2\pi \\ V_0 &= 400 \text{ volts} \end{aligned}$$

ϕ	θ
0	0°
$\pi/4$	31
$\pi/2$	44
$3\pi/4$	54
π	62
$5\pi/4$	69
$3\pi/2$	75
$7\pi/4$	81
2π	86

These values are plotted on Fig. 8. It will be evident that by forming a surface on a disc or cylinder where the angle of incidence varies with the azimuth angle according to this graph, that as the circular beam b sweeps around its 360° path, the number of secondary electrons collected will vary directly with the azimuth angle, giving the desired sawtooth pattern.

Similar curves have been plotted in Fig. 9, one of them showing a curve used for slow sweep in an engine analyzer to give a sawtooth curve, again varying with the 360° azimuth angle. The curve differs from that shown in Fig. 8 primarily in staying within a smaller range of angles of incidence in order to hold down the axial length of the target and make one which is more practical than the calculations illustrated in Fig. 8 would be. As will be seen, the angle of incidence is kept between 0° and 60° from normal. The resultant target 73 is illustrated in Figs. 10 through 15, where an effort has been made to show the curve b in perspective and in elevation. The target 73a shown in Fig. 11 differs from that shown in Fig. 10 only in extending in the opposite axial direction, so that the center point is closer to the electron gun than the edges (in both Figs. 10 and 11 the beam b is assumed to be coming from the top down), while in Fig. 10 the axial center is farther from the electron gun than are the sides. The three-dimensional structure is a complex one to illustrate in two dimensions, but is not a difficult one to build, especially after the first one has been constructed and used as a matrix for molding the others. The collector ring 74 is spaced as closely as practical to the target in each instance, and is protected by a shield 75. When the target shown in Figs. 10-15 is used in the circuit shown in Fig. 7, the signal output from a circular input sweep is a substantially perfect sawtooth curve going from minimum voltage at 0° azimuth to maximum voltage at just before 360° azimuth.

A fast sweep sawtooth generator

As Fig. 9 shows, it is also possible to construct a target where the angle of incidence varies from 0° to 60° within approximately 45° of azimuth, and the target may provide substantially no change between the 45° of azimuth and 360°. Such a target 80 is illustrated in perspective in Fig. 16, with a view in elevation in Fig. 17. The use of this target will be explained later in connection with an analyzer, and it will be obvious that it can be used for any purpose wherein a steep sawtooth is desired for one portion of a time interval and where no change is desired for the remainder of the interval.

Target adapted to produce a square wave

A circular sweep may also be used to produce a square wave by utilizing a target 85 like that of Figs. 18 and 19, in which only two different angles of incidence are used.

Thus, one portion 86 of the target 85 may provide a 0° angle of incidence, while the remainder 87 of the target 85 provides a 60° angle of incidence. Suppose that the 0° angle of incidence extends 20° of azimuth, while the remaining 340° provides a 60° angle of incidence. Such a target will provide a sharp change at each end of the 60° portion between a relatively low ratio of secondary emission to a relatively high ratio. The result in the output is what is known commonly as a square wave, though it may be rectangular and is not necessarily square. Such a target may be used wherever a square wave output is desired and where it is easy to produce a circular sweep in the cathode-ray tube containing the target.

Composite target

As Fig. 20 illustrates, it is possible to provide a double target 90 in the same tube by forming the target disc so that one annular surface (the target 91) between two radii varies according to one curve like that of Fig. 9, while another annular portion (the target 92), whose radii are all either greater or lesser than either extreme radius of the former portion, has a different shape. The curve here illustrated includes a slow sweep annulus and an annulus in which the sawtooth change between 0° and 20° of azimuth has half of the change in voltage along a smooth slope in the output diagram, while a similarly smooth slope produces the other half of the voltage change in the following 340°. In such a tube it is necessary to provide a control of the radius by any of several well known means, so that the electron beam can be switched from one annular portion to the other at will, but will remain within the chosen annulus.

Simple analyzer using the present invention (Fig. 21)

While some of the applications of my invention involve complex circuits and apparatus, many of the basic principles are illustrated in the simple analyzer shown in Fig. 21, and the more complex applications will be better understood after considering this simple and practical embodiment.

There are many ways of obtaining a circular sweep, some of which are shown in the drawings, and one of the simplest is shown in Fig. 21. An engine 100 to be analyzed drives a rotatable magnet 101 in a two-phase generator 102 at engine cycle speed, which, in an airplane engine, is one-half the crankshaft speed. The two-phase generator 102 has two stationary coils 103 and 104 located ninety degrees out of phase. Lead wires 105 and 106 extend from the coil 103 to a cathode-ray tube 110 (for some applications it may be desirable to include a transformer or an amplifier in these leads), and place a varying (sine wave) potential across one magnetic deflection coil 111. Similarly, lead wires 107 and 108 from the coil 104 place a varying (sine wave) potential, 90° out of phase with the prior signal, across another magnetic deflection coil 112, perpendicular to the coil 111. This affects an electron beam 113 causing it to move in a circular path 114 once per engine cycle. Flexible leads 115 or slip rings, may be used to connect the coils 111, 112, to their leads 105, 106 and 107, 108, so that the point of initiation of the circular sweep may be adjusted relative to the engine generator 102. This method of obtaining a circular sweep is well known in the art. Other methods may also be used, including those shown in the co-pending application by John E. Lindberg, Jr., Serial Number 517,577, filed June 23, 1955.

As the beam b moves in a circle, it impinges on a target 73 like that shown in Fig. 7 and in Figs. 10-15, so that the secondary emission will vary as a straight-line function of the azimuth angle of the beam b . The collector ring 74 therefore will provide an output signal which varies as shown in Fig. 22. Thus, the circular beam 114, generated by two sinusoidal voltages 90° out

of phase, results in a sawtooth sweep 120 with a linear slope (see Fig. 22).

This sawtooth sweep 120, which may be amplified, if necessary, by an amplifier 121 may then be impressed on the main cathode-ray tube 125 of the analyzer, across its "horizontal deflection" plates 126, 127. This causes the electron beam of the tube 125 to move from left to right at the same rate as the engine cycle speed, and then to move practically instantaneously back from right to left (or vice versa, if desired). The azimuth cycle of beam *b* is directly tied to the engine cycle as described above. Therefore, the indicator sweep voltage developed by the electron beam *b* at each azimuth point of its sweep corresponds to a point on the engine cycle. Thus the electron beam motion on the indicator tube is at all times tied to the engine cycle. Therefore, the position of the beam relative to the engine cycle is constant, with any given target. The rate of speed of the electron beam is constant if the engine speed is constant; if the engine speed changes, the speed of movement of the beam changes. For example, when using the target 73, the sweep plates 126, 127 are impressed with a sawtooth sweep voltage in exact synchronization with the engine-driven two-phase generator 102 and its circular sweep at the tube 110.

Across the other, "vertical deflection," plates 128 and 129 of the tube 125 is impressed the signal from the engine itself, which may be of the type shown in Patent No. 2,518,427 or may be of another type. The signal may be from an engine magneto (for studying ignition) or may be from a vibration pickup or any other engine-generated signal may be used.

Operation of the Fig. 21 apparatus

When the engine 100 is running, the two-phase generator 102 generates a circular sweep 114 at the tube 110, necessarily perfectly synchronized at every angular position with the engine cycle. The circular beam 114 impinging on the target 73 causes secondary emission, and electrons are picked up by the collector 74. A change in secondary emission changes the output voltage across the terminals 130 and 131 as the beam 113 passes around its circular path. This output voltage, properly amplified if necessary, is impressed across the sweep plates 126 and 127 of the analyzer cathode-ray tube 125 resulting in a sweep circuit there. Meanwhile, the signal plates 128, 129 are impressed with a signal from the portion of the engine being analyzed, as provided in the Patent #2,518,427 or in other engine analyzer circuits, giving a resultant pattern on the scope 125. When the engine is accelerated, both the engine-initiated signal and the engine-generated sweep always remain in perfect phase. The point of initiation thereof is varied by varying the positions of the two coils 111, 112 relative to the target 73.

The use of the full 360° sawtooth sweep gives the linear curve 120 plotted in Fig. 22, and this means that the 360° sweep of the beam *b* will read the full 720° of the engine crankshaft cycle corresponding to a complete engine cycle. Thus, if an ignition diagram is obtained in the viewing tube, patterns for every cylinder appear as shown in the pattern 140 in Fig. 23.

Fast sweep structure in an analyzer

Targets like those shown in Figs. 16 and 17 may be used to provide a fast sweep in an engine analyzer so as to give a large picture in the viewing tube of fewer than all the cylinders. For example, in an 18-cylinder engine, by having the full change in secondary emission take place over 20° of arc, one cylinder only will appear, as shown in the pattern 141 in Fig. 24. The output curve is therefore like the curve 142, or its reverse, shown in Fig. 22, which has a steep portion 143 in the first 20° of the beam *b* (corresponding to 40° of engine cycle), and remains constant for the remainder 144 of the cycle.

Slow-fast sweep

A structure like the inner ring of the Fig. 20 device may be used in an engine analyzer to give in the viewing tube an enlarged diagram of, say, one cylinder, while still showing all the cylinders. Thus, an output curve like the curve 150 shown in Fig. 22 may be obtained having a steep slope portion 151 for the first 20° corresponding to half the voltage change of the cycle and a much less steeply sloped portion 152 corresponding to 340° accommodating the remainder of the voltage change. A resultant ignition diagram 153 is shown in Fig. 25.

A circuit diagram for a composite analyzer (Figs. 26 and 27)

The circuit of Fig. 26 may be used to obtain the results shown in Fig. 27, in which there are two cathode-ray tubes 200 and 201 side by side. The tube 200 presents to the flight engineer or other viewer a picture of the entire engine cycle (showing here the ignition diagram 202 for all the cylinders), while the other tube 201 shows a fast sweep pattern 203 across one cylinder only, it being possible to shift the pattern in the tube 201 from one cylinder to another and obtain an enlargement of the performance of each cylinder while at all times getting a view of all the cylinders.

Fig. 26 also demonstrates the use of a modified form of sweep generator tube 200 incorporating certain unique characteristics, as a part of an engine analyzer system. The system uses the two cathode-ray tubes, the sweep generator tube 200 and the indicator tube 201. The engine 204 to be analyzed drives a three phase generator 205 at engine cycle speed through a proper gear train arrangement. This engine-driven generator 205 is connected through a condition selector switch 206, which is preferably a rotary switch providing one position for each engine to automatically select the proper engine-driven generator and phase through switches 207, 208, and 209. At the same time, the proper connections are made to the condition information to be displayed on the indicator tube 201, this being obtained through selection switches 210, 211, and 212. From the condition selector switch 206, the signals from switches 207, 208, and 209 pass to a three-phase deflection yoke 213 which is placed around the sweep generator tube 200. Rotation of a permanent magnet 214 at engine cycle speed generates a rotating field in the deflection yoke 213 and produces a circular sweep of the cathode-ray beam on target 215 in step with the engine cycle. Rotation of the deflection yoke 213 in azimuth relation to the sweep generator tube 200 changes the phase relationship between the moving engine cycle and the position of the rotating electron beam as it strikes the target 215. This cycle switch control thus makes it possible to change the position of initiation of the sweep. In other words, the deflection yoke 213 is a cycle switch, and rotation of the yoke 213 in relation to an engine cycle index, simultaneously changes the initiating point in a corresponding manner of the oscillogram 203 displayed on the indicator tube 201.

The leads 216, 217, and 218 are provided with either a flexible section or with slip rings to permit rotation of the magnetic deflection yoke 213 through more than 360° azimuth, thus permitting a complete survey of the engine cycle. The use of this deflection system in the engine analyzer has previously been disclosed in co-pending application Serial No. 517,577, filed June 23, 1955.

A sweep selector switch 220 is made up of two sections 221 and 222. The switch portion 222 controls the negative D.C. voltage applied to an electrode 223 and thereby controls the size of the circle made by the electron beam 224. With the switch 222 in position "S," the least negative voltage is applied to the electrode 223; therefore the electron beam 224 strikes an inner target area 225, which by design may generate the slow sweep

as previously described. When the switch 222 is in position "C," it provides a more negative voltage on the electrode 223, and therefore causes the electron beam 224 to strike an outer target area 226. The outer target area 226 may have the form shown in Fig. 20, which generates a composite sweep.

When the selector switch portions 221 and 222 are placed in position "F," the switch 222 selects the same negative voltage as selected when it was in position "C," so that the electron beam 224 again strikes the target area 226, generating a composite sweep. However, at the time the switch 222 is in position "F," the switch 221 is also in position "F." The switch 221 selects the amount of voltage developed by the secondary emission current collected by an electrode 227 and passing through resistors 228 and 229 to ground. Resistors 228 and 229 are of equal value; therefore, when the switch 221 is placed in position "F," twice as much voltage is picked up as is picked up at points "S," and "C." In positions "S" and "C," full screen width on the indicator tube 201 represented full sweep voltage. In position "F," twice as much deflection voltage is developed; therefore full sweep across the indicator tube 201 represents one-half the sweep voltage. This therefore develops a fast sweep using the same target as previously used for composite sweep. See the curve 150 in Fig. 22.

A condition selector switch 230 is preferably made up of three rotary switch sections 231, 232, and 233. The condition selector switch 230 selects the conditions to be placed on the vertical plates of the cathode-ray tube indicator 201 for study. Normally, the condition switch 230 is combined with the engine selector switch 206 so that a single switch selects the engine and condition to be studied. This arrangement of circuit wiring is shown in Patent No. 2,518,427; when the switch 230 is in "vibration" position, the information obtained from a vibration pickup 234, mounted on the engine 204 is passed through an amplifier 235 to amplify its signal and is then placed on one vertical plate 236, the other vertical plate 237 being grounded. When the condition switch 230 is placed in "ignition" position, the ignition signal taken from a grounding wire of magneto 238 is applied directly to the vertical deflection plate 236 of the indicator tube 201. When the condition selector switch 230 is placed in "time" position, electrical energy inductively picked up by an inductive timing pickup 240 is passed through a vertical amplifier 241 and then to the vertical deflection plates 236 and 237 of the indicator tube 201. The inductive pickup 240 is placed on one known ignition lead on the engine 204 and serves as a marker to check the timing of the analyzer to the engine 204.

The target 215 may be coated with a fluorescent coating material by using a transparent stannic chloride coating on glass as the target 215 and adding to the stannic chloride coating a suitable luminescent phosphor type of coating, such as is used in cathode-ray oscilloscopes. With the target 212 so coated, the device of Fig. 26 may be used to obtain the results shown in Fig. 27. In this event a condenser 241, switch 242, and leads 243, 244 are used to connect the vertical deflection plate 236 to the electrode 223, so that the signal impressed on the plate 236 is also simultaneously impressed on the electrode 223. Otherwise the condenser 241, switch 242, and leads 243, 244 are omitted. Since voltage applied to electrode 223 causes a radial deflection of the electron beam (positive voltage decreases the radius and negative voltage increases radius) the diagram 202 results. The two cathode-ray tubes 200 and 201 preferably are arranged side by side. The tube 200 presents a picture of the entire engine cycle (e.g., the ignition diagram 202 for all the cylinders), while the other tube 201 shows a fast sweep pattern 203 across one cylinder only. It is also possible to shift the pattern in the tube 201 from one cylinder to another and obtain an enlargement of the

performance of each cylinder while at all times getting a view of all the cylinders. The diagram portion appearing on the sector 212 is always the part that is enlarged and presented as the diagram 203 on the tube 201.

Modified form of target for use in digital computer (Fig. 28)

The perspective view of Fig. 28 illustrates, somewhat diagrammatically, the construction of a target 250 for use in a digital computer. The target 250 is composed of 10 segments, 251, 252, 253, 254, 255, 256, 257, 258, 259, and 260. It will be noted that each segment has a different slope from the other segments and that the segments get progressively steeper from a 0° angle of incidence at target sector 251 to approximately a 70° angle of incidence at the segment 260. The resultant secondary emission is collected on the collector rod 261.

Since each section of the target 250 has a different secondary emission ratio and since a circuit connected to the collector 261 can be set up according to conventional manner to produce a desired result for a digital computer, this illustrates another use for the secondary emission apparatus of this invention. Obviously, the same general theory can be used in constructing a binary and ternary or any other form of computer and a target of different configuration can also be used in analogous and similar situations rather than being limited to computers.

Another modified form of tube (Fig. 29)

A tube 270 in Fig. 29 has a target 271 as a portion of an end wall 272 of the tube. The target 271 constitutes a curved plane or a warped surface, according to the use to which the device is to be put. A suitable type of deflection means 273 and 274 such as that shown in Fig. 4 is used, in much the same manner as in Fig. 4, but in this instance the sweep is used to vary the position of the beam surface-wise rather than simply along one dimension. A collector means 275 is again employed in the manner already described.

It will be noted that the target 73 of Figs. 10-15, the target 80 of Figs. 16 and 17, and the target 85 of Figs. 18 and 19 are so constructed that the angle of incidence θ is constant with respect to the radius, so that the radius of the deflected beam b can change without changing the effect. On the other hand, the target 61a in Fig. 6a and the target 271 in Fig. 29 are so constructed that any change in radius does ordinarily vary the angle of incidence θ . The target 61a, in fact is varied only by radial changes and is unaffected by changes in azimuth, so long as the radius remains unchanged. (So far as the use of the target 61a in the manner shown in Fig. 6 is concerned, of course the beam b stays constant; so the radial change is provided by the motion of the target.) The target 90 in Fig. 20 is a two-level target in which a change of radius on either level does not change the angle θ , unless the change shifts the beam from one level to the other. The target 271 of Fig. 29 represents a general case, wherein the shape of the target can be preformed to result in any desired control of the angle θ relative to position, for obtaining any desired voltage effects. Thus a curve 276 might result from a circular sweep (see Fig. 22), or the curve 277 might be obtained, or any other curve desired can be obtained.

To those skilled in the art to which this invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. The disclosures and the description herein are purely illustrative and are not intended to be in any sense limiting.

What is claimed is:

1. In an engine analyzer, engine-operated means to generate a cyclic-path cathode-ray sweep beam in cycle with its engine; a target upon which said beam impinges so as to produce secondary electron emission, the in-

tensity of which changes in a predetermined manner during each cycle; a collection ring adjacent said target for collecting secondary electrons so emitted, so that the motion of said sweep generates a secondary electron current that varies in a predetermined relation depending on the angular position of said beam; an engine analyzer tube having deflection means; and means to vary the potential difference across said deflection means with said secondary electron current.

2. In an engine analyzer, means to project a cathode-ray beam; a target upon which said beam impinges and produces secondary electron emission; engine operated means to vary the angle of incidence of said beam upon said target in cycle with said engine so as to vary the intensity of secondary electron emission in a predetermined manner during each cycle; a collector for secondary electrons so emitted; an engine analyzer cathode-ray tube having two deflection means; means to impress an engine signal across one said deflection means; and means to impress a potential difference varied by said secondary electron current across said second deflection means.

3. In an engine analyzer, engine-operated means to generate a cyclic-path cathode-ray sweep beam in cycle with the engine that generates it; a target against which said beam impinges and thereby emits secondary electrons; a collection means adjacent said target for collecting the emitted secondary electrons; an engine-analysis cathode-ray tube having two mutually perpendicular pairs of parallel deflection plates; means to obtain an analyzer signal from some portion of the same engine and to impress it across one pair of deflection plates; and means to impress a voltage varied with said secondary electron emission across the other pair of deflection plates.

4. In an engine analyzer, engine-operated means to generate a generally circular cathode-ray sweep beam in cycle with its engine; a target upon which said beam impinges so as to emit secondary electrons, the angle of incidence of said beam on said target bearing a predetermined relation with the cyclic position of said beam so as to produce a predetermined resultant variation in secondary electron emission; a collection means for collecting the emitted secondary electrons; an engine analyzer tube having sweep deflection means; and means to vary the potential difference across said sweep deflection means with the collection of emitted secondary electrons on said collection means.

5. In an engine analyzer, engine-operated means to generate a circular cathode-ray sweep beam of primary electrons in cycle with the engine that generates it; a target against which said beam impinges and which then releases secondary electrons, said target being shaped to vary the ratio of secondary to primary electrons according to a predetermined relation during each cycle; a collector means for collecting emitted secondary electrons; means for obtaining a correspondingly varied potential difference therefrom; an engine-analysis cathode-ray tube having two mutually perpendicular pairs of parallel deflection plates; means to obtain an analyzer signal from some portion of the same engine and to impress it across one pair of deflection plates; and means to impress a multiple of said potential difference across the other pair of deflection plates.

6. The analyzer of claim 5 wherein said primary electron sweep beam is provided with an axial deflection means isolated from said target and electrically connected in parallel with said one pair of deflection plates.

7. The analyzer of claim 6 wherein said target is transparent and includes luminescent means for observation of the path of the sweep beam thereon.

8. In an engine analyzer, means to generate a primary electron beam; a target upon which said beam impinges so as to produce secondary electron emission; means to move said beam and target relatively to each other in cycle with the engine being analyzed, the intensity of said

secondary emission changing in a predetermined manner during each cycle; a collector for secondary electrons so emitted, so that the motion of said sweep generates a secondary electron current that varies in a predetermined relation depending on the angular position of said beam; an engine analyzer tube having deflection means; and means to vary the potential difference across said deflection means with said secondary electron current.

9. In an engine analyzer, engine-operated means to generate a circular cathode-ray sweep beam of primary electrons in cycle with the engine that generates it; a target against which said beam impinges and which then releases secondary electrons, said target being shaped to vary the ratio of secondary to primary electrons according to a predetermined relation during each cycle; a collector means for collecting emitted secondary electrons; means for obtaining a correspondingly varied potential difference therefrom; an engine-analysis cathode-ray tube having first and second deflection means; means to obtain an analyzer signal from some portion of the same engine and to impress it across said first deflection means; and means to impress a multiple of said potential difference across said second deflection means.

10. An electronic tube for utilizing the phenomenon of secondary electron emission, comprising a target capable of emitting secondary electrons; means for projecting a beam of primary electrons at said target; collection means for secondary electrons emitted by said target; and two sets of deflection means operating on said beam so as to vary the direction from which said beam comes when it strikes the target at substantially a single point, to vary secondary electron emission from said target by varying the angle of incidence of said beam relative to said target without changing the point at which the beam strikes said target.

11. An electronic tube for utilizing the phenomenon of secondary electron emission, comprising a target capable of emitting secondary electrons; means for projecting a beam of primary electrons at said target; collection means for secondary electrons emitted by said target; and means to deflect said beam to vary secondary electron emission by varying the angle of incidence of said beam relative to said target while causing the beam to strike the target at the same point.

12. An electronic tube for utilizing the phenomenon of secondary electron emission, comprising a target having a plurality of segments capable of emitting secondary electrons and having different response characteristics; means for projecting a beam of primary electrons at said target; collection means for secondary electrons emitted by said target; means to vary secondary electron emission by varying the angle of incidence of said beam relative to said target; and selection means for directing said beam at any one said segment during operation.

13. An electronic tube for utilizing the phenomenon of secondary electron emission, comprising a target having a series of segments capable of emitting secondary electrons, each having a uniform and different angle of incidence; means for projecting a beam of primary electrons at said target; collection means for secondary electrons emitted by said target; and means to move said beam successively across said segments in response to an impressed signal.

14. The analyzer of claim 2 having means for changing the initiation point of said sweep beam relative to the engine cycle.

15. The analyzer of claim 2 wherein said target comprises a plurality of annular target areas, each area having different response characteristics from each other area, and means for changing the radius of said sweep beam to cause it to impinge completely on any one of said areas during its cycle.

16. An electronic tube for utilizing the phenomenon of secondary electron emission, comprising an anode hav-

ing a target area capable of emitting secondary electrons; an electron gun for projecting a beam of primary electrons at said target; an annular cylindrical collection ring for the secondary electrons emitted by said target, said ring being larger in diameter than said target area and spaced adjacent said anode between said anode and said electron gun; an annular conductive shield between said gun and said ring having an inner periphery smaller than said ring and an outer periphery larger than said ring, for preventing electrons in said beam from directly striking said ring; and means to vary secondary electron emission by varying the angle of incidence of said beam relative to said target area, said last-named means comprising two sets of deflection means operating on said beam so as to vary the direction from which said beam comes when it strikes the target at substantially a single point.

References Cited in the file of this patent

UNITED STATES PATENTS

2,250,528 Gray ----- July 29, 1941

20

328,680

2,374,666
2,406,982
2,431,569
2,438,709
2,470,731
2,491,390
2,502,132
2,503,949
2,518,427
2,535,055
2,537,150
2,645,751
2,700,151
2,700,626
2,740,069
2,787,760

Cunniff ----- May 1, 1945
Zworykin et al. ----- Sept. 3, 1946
Labin ----- Nov. 25, 1947
Labin et al. ----- Mar. 30, 1948
Sziklai ----- May 17, 1949
Olson ----- Dec. 13, 1949
Efromson et al. ----- Mar. 28, 1950
Jensen et al. ----- Apr. 11, 1950
Lindberg et al. ----- Aug. 8, 1950
Ferguson ----- Dec. 26, 1950
Miller ----- Jan. 9, 1951
Byerlay ----- July 14, 1953
Flory ----- Jan. 18, 1955
Mendenhall ----- Jan. 25, 1955
Minto ----- Mar. 27, 1956
Sammis ----- Apr. 2, 1957

FOREIGN PATENTS

Great Britain ----- Feb. 1, 1929

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,974,274

March 7, 1961

John E. Lindberg, Jr., et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 40, for "the", second occurrence, read -- a --; line 49, after "may" insert -- be --; column 8, line 4, the left-hand portion of the formula should appear as shown below instead of as in the patent:

$$d_{\theta} =$$

column 11, line 48, for "the", second occurrence, read -- my --.

Signed and sealed this 3rd day of October 1961.

SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD

Commissioner of Patents

USCOMM-DC

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 2,974,274

March 7, 1961

John E. Lindberg, Jr., et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 6, line 40, for "the", second occurrence, read -- a --; line 49, after "may" insert -- be --; column 8, line 4, the left-hand portion of the formula should appear as shown below instead of as in the patent:

$$d_{\theta} =$$

column 11, line 48, for "the", second occurrence, read -- my --.

Signed and sealed this 3rd day of October 1961.

SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD

Commissioner of Patents

USCOMM-DC