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APPARATUS FOR DISTINGUISHING BETWEEN FLUORESCENT AND PHOSPHORESCENT MARKINGS

Filed April 9, 1962 3 Sheets-Sheet 1

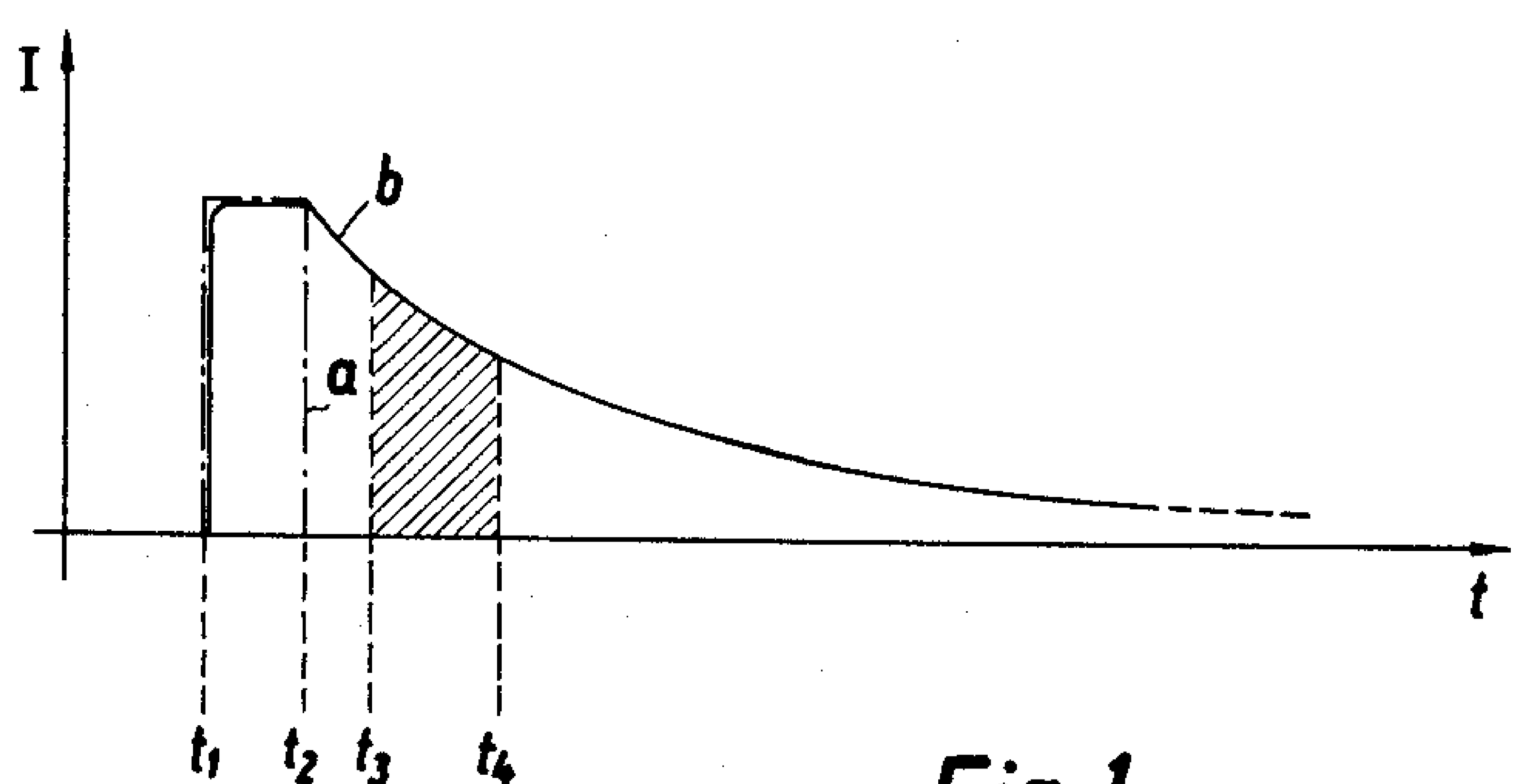

Fig. 1

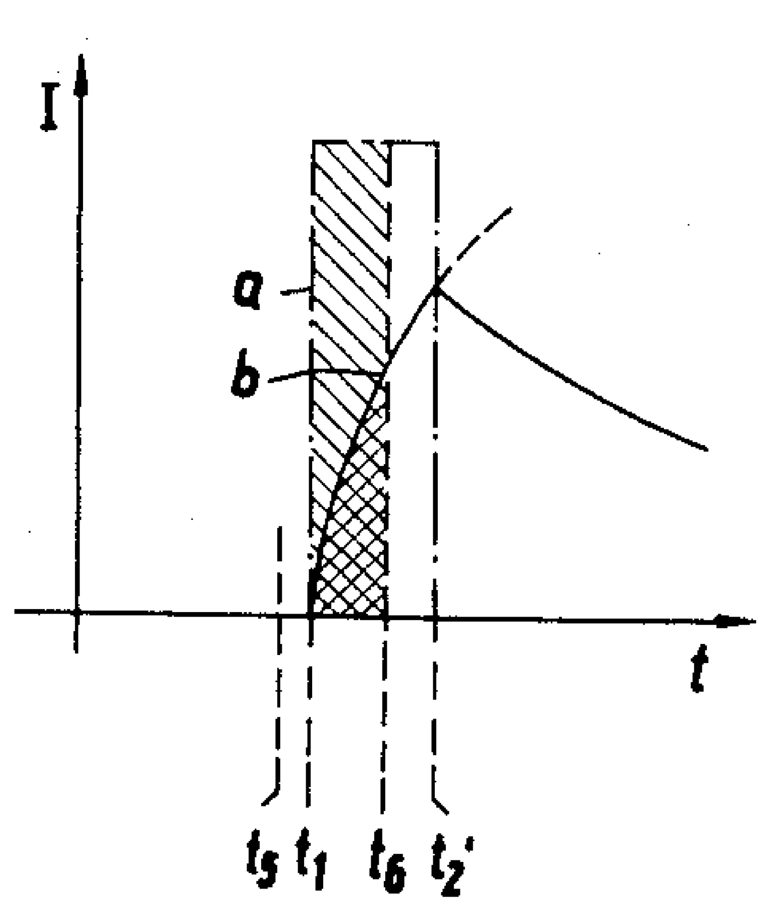

Fig. 2

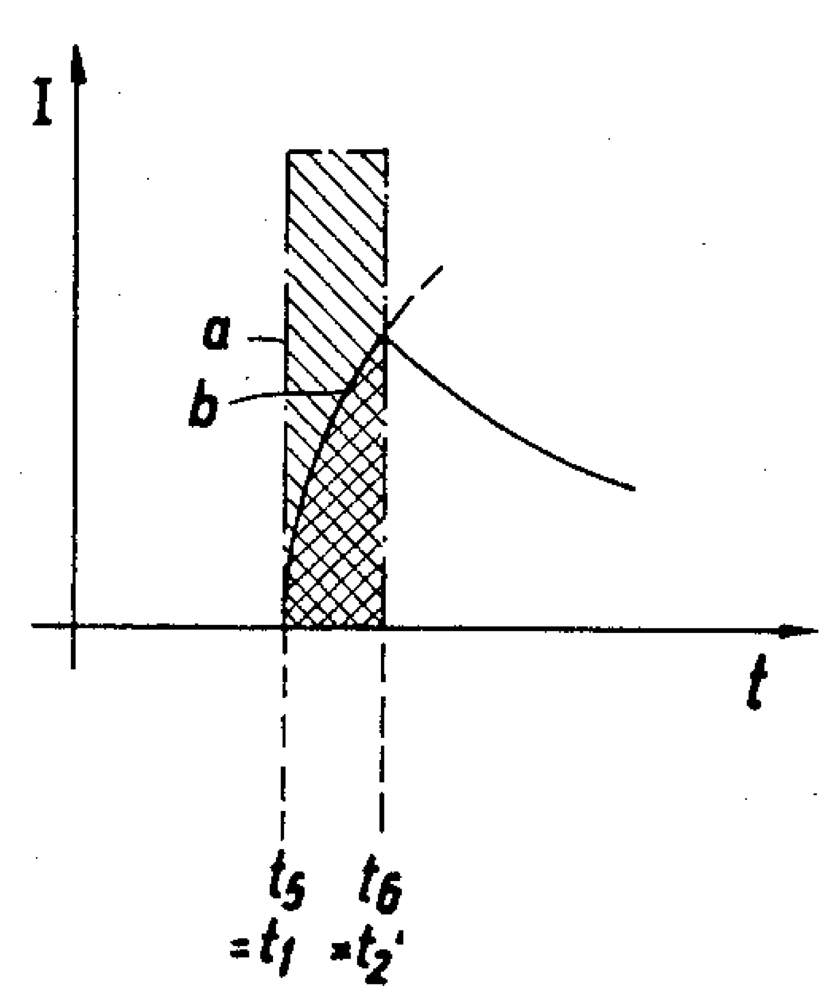

Fig. 3

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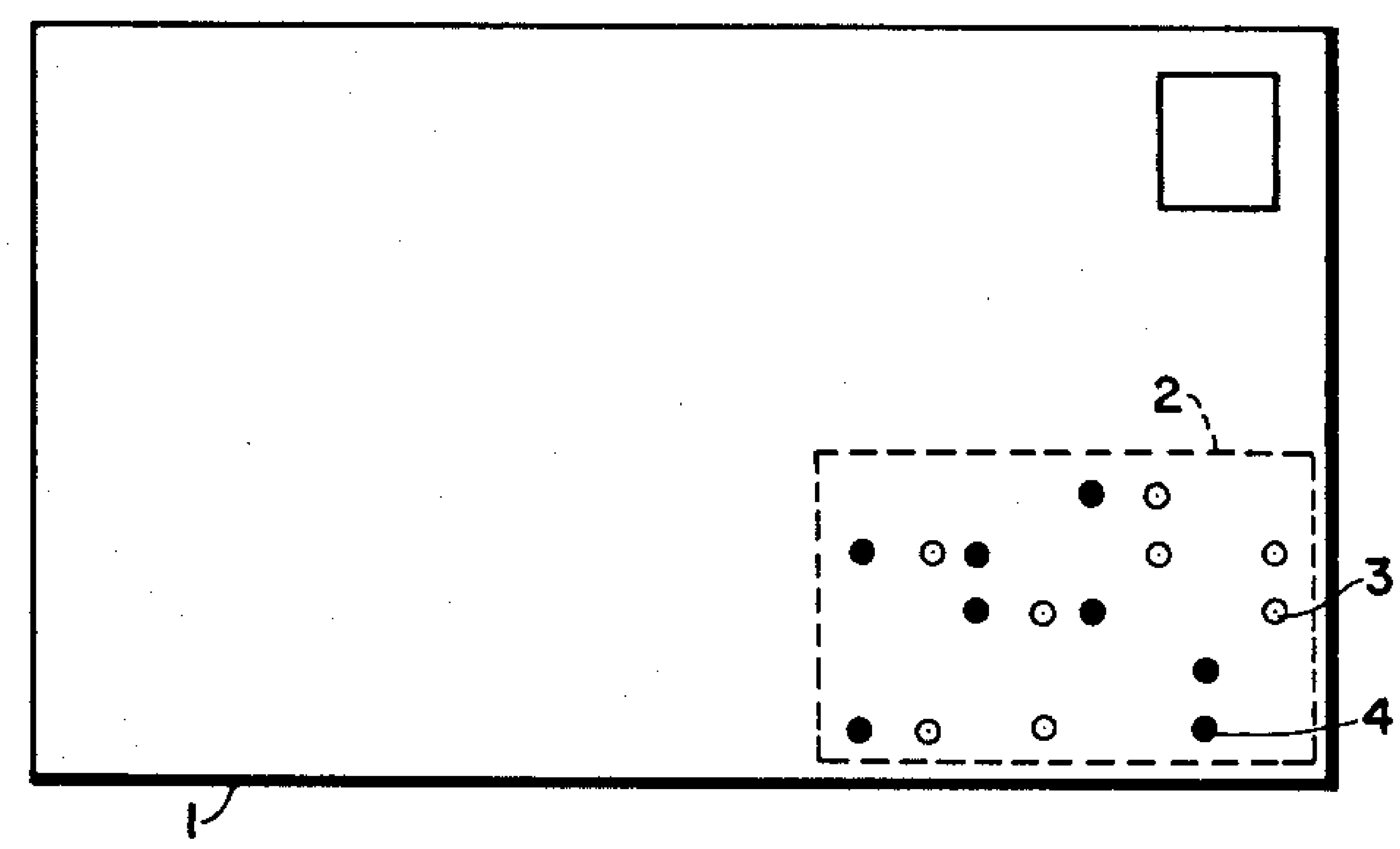

FIG. 4.

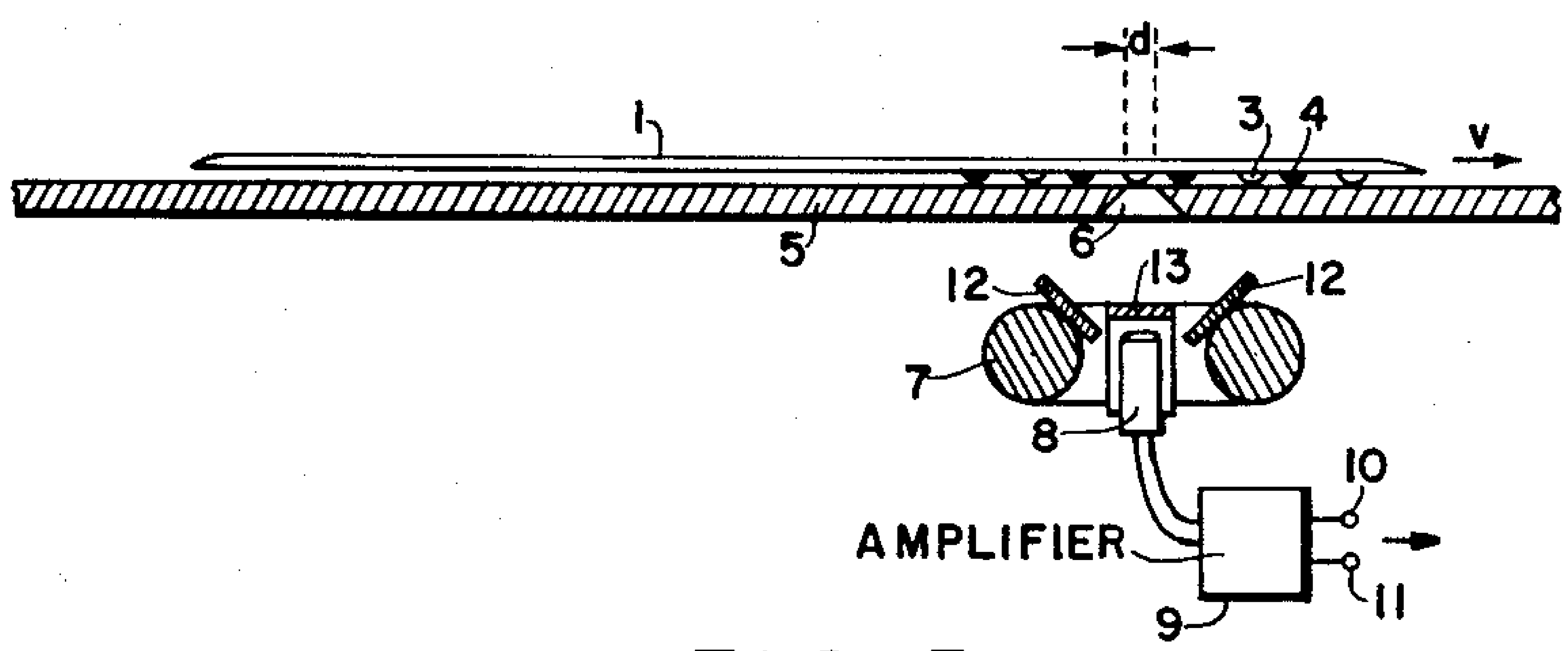

FIG. 5.

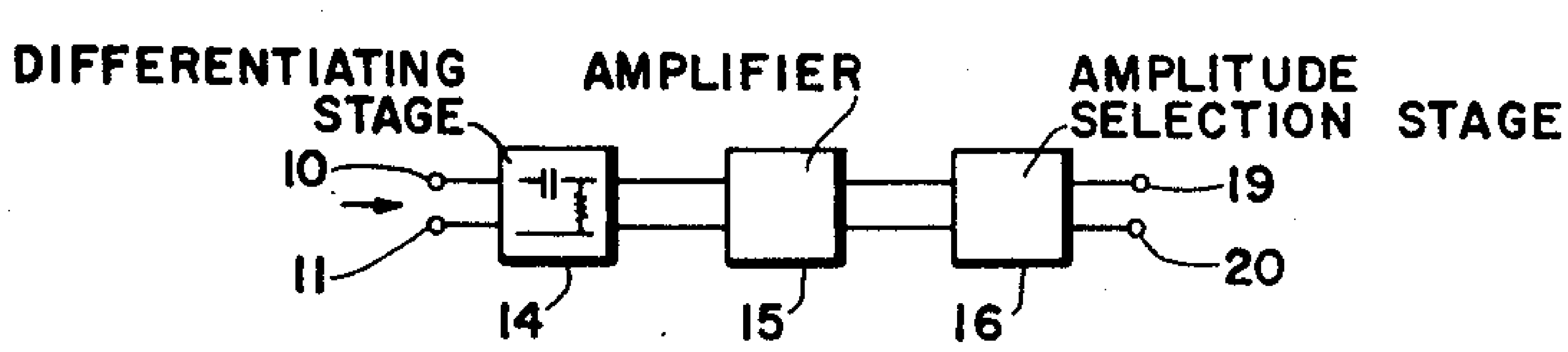

FIG. 6.

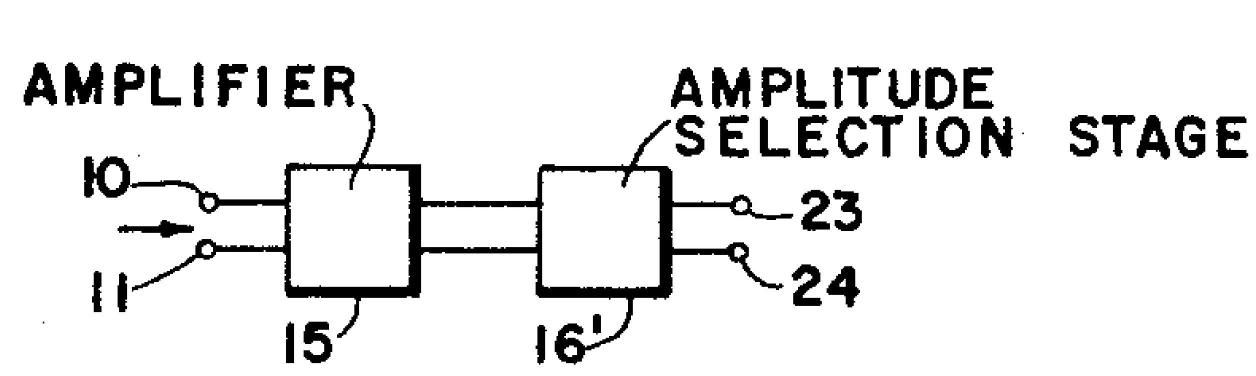

FIG. 7.

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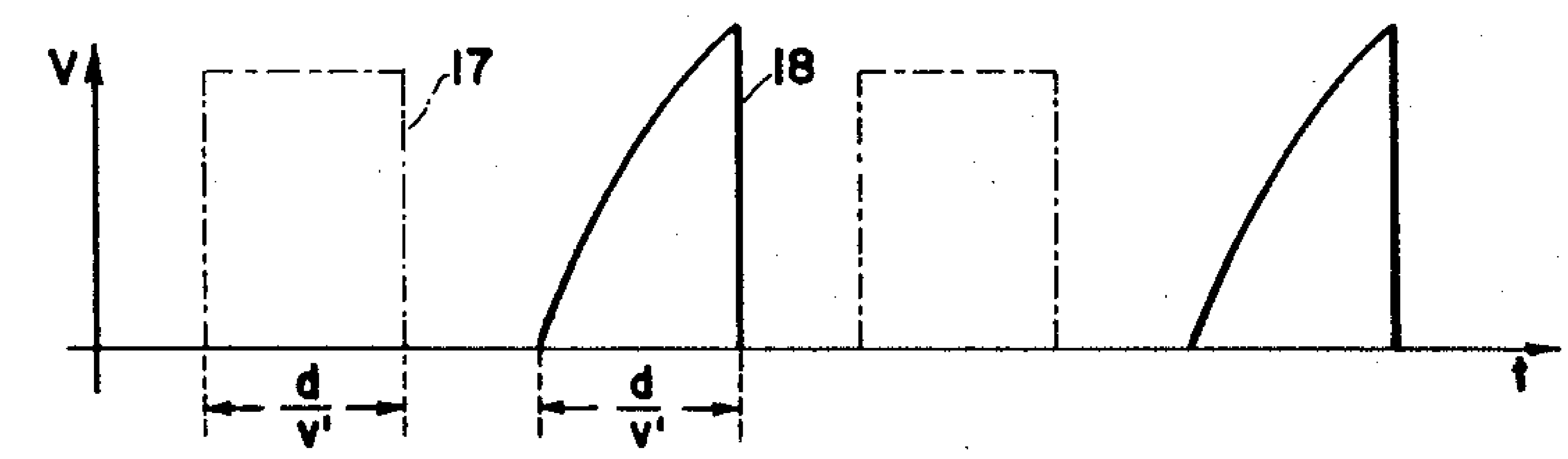

FIG. 8a.

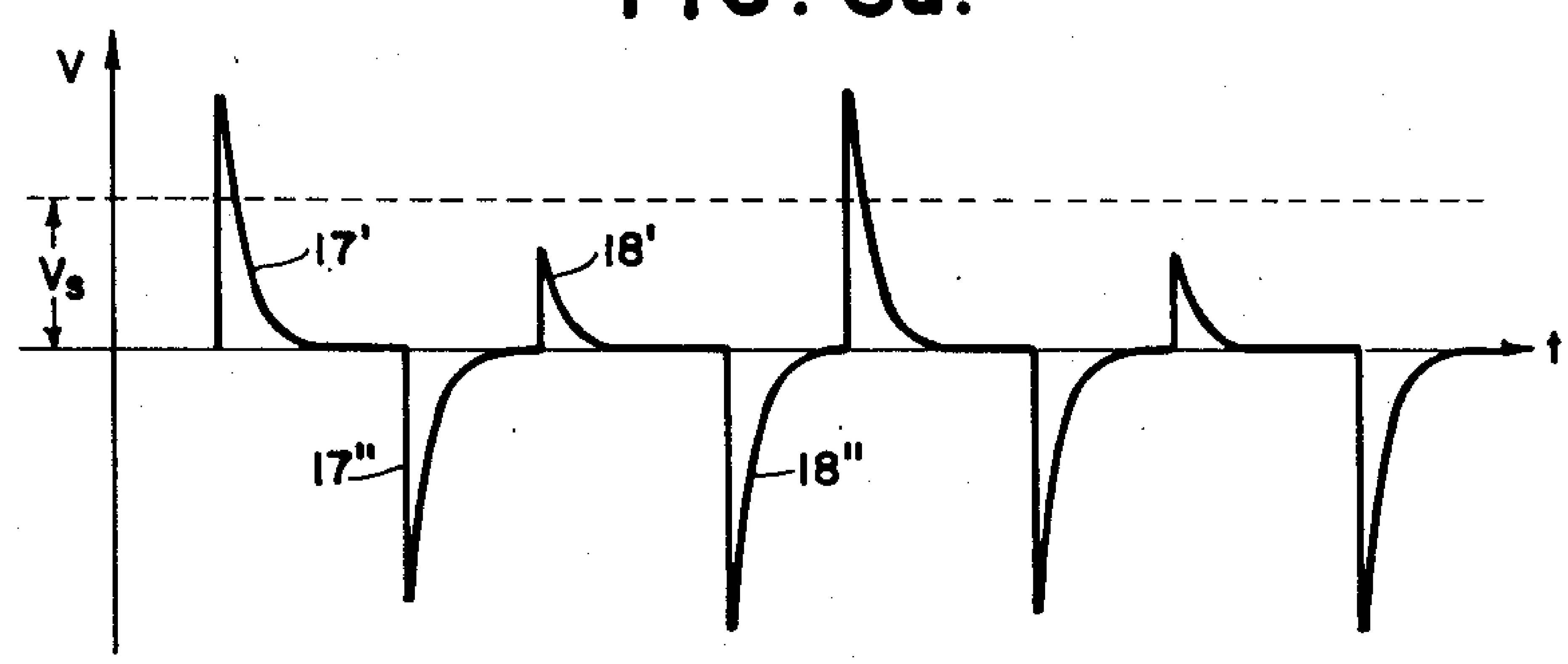

FIG. 8b.

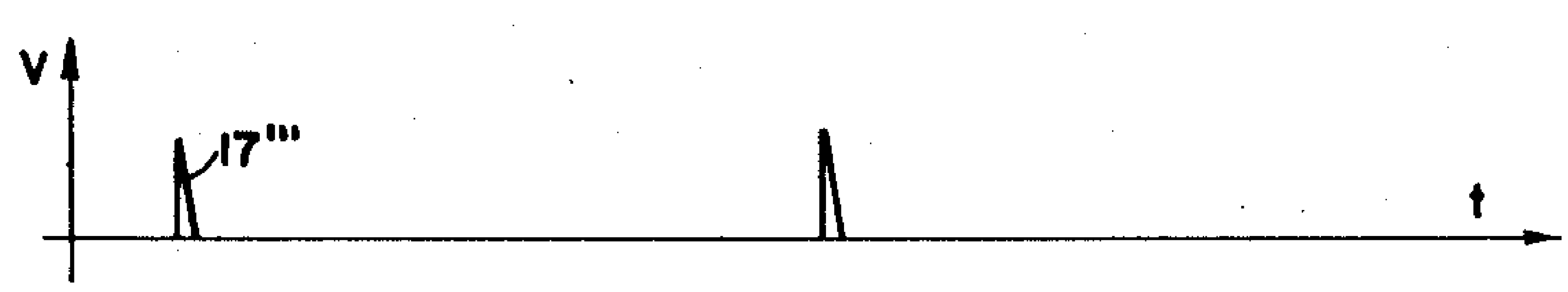

FIG. 8c.

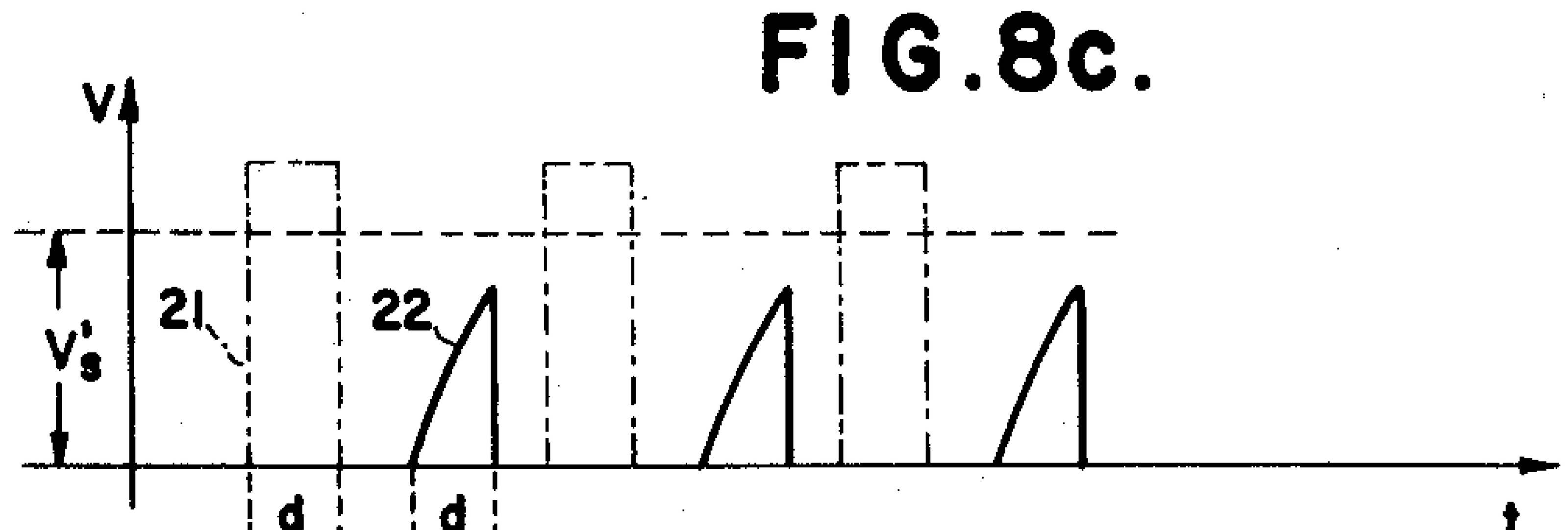

FIG. 9a.

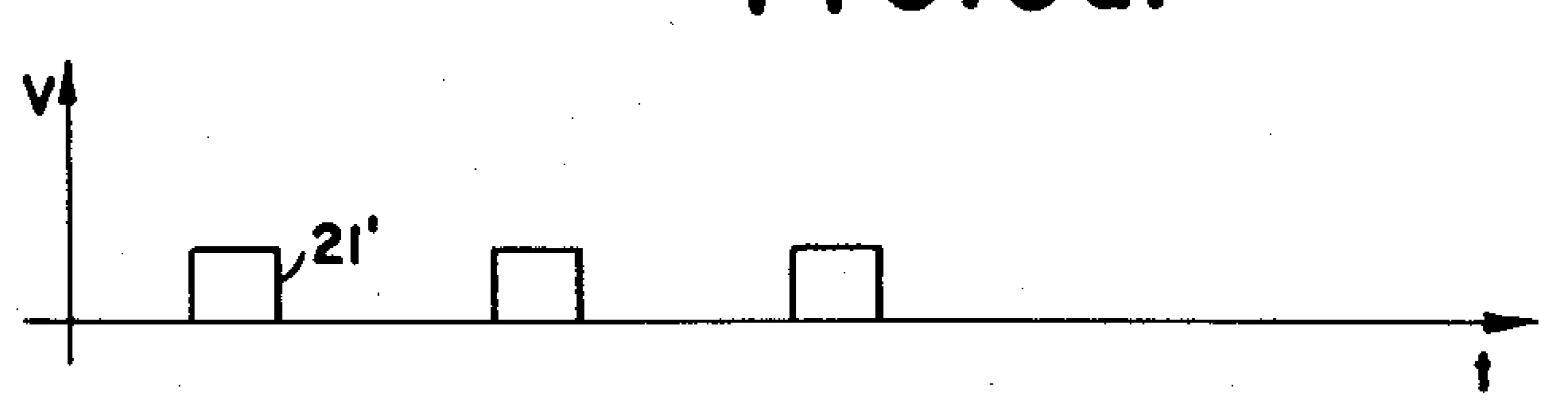

FIG. 9b.

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1

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APPARATUS FOR DISTINGUISHING BETWEEN FLUORESCENT AND PHOSPHORESCENT MARKINGS

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Claims priority, application Germany, Apr. 15, 1961, T 19,989
7 Claims. (Cl. 250—71)

The present invention relates to a method and apparatus for scanning articles bearing luminescent markings, wherein an exciting radiation is directed against the markings and a receiving device responds to the secondary emission emanating from the markings. Such a method and apparatus, while not limited to, is particularly useful in the field of automatic mail sorting, the term "mail" or "item of mail," as used throughout the instant specification and claims being deemed to include not only letters, post cards, printed matter, parcels, or the like, customarily handled by postal authorities, but any item or article which is conveyed and which must be routed to a certain destination.

It is known that, in the field of automatic mail sorting, each individual item has to carry markings which are suitably coded to represent the destination and which can be read or scanned by machines, i.e., by a non-human means, which markings thus serve to guide the item to its intended destination. The markings may be of electrically conductive material, or of magnetizable material, or of a material which, upon being irradiated or illuminated with, for example, ultraviolet light, will cause secondary emissions which are within the range of visible light. The items are then moved past a scanning apparatus whose output signal controls the switches of a distributing system through which the mail is passed in such a manner that the items are sent to destinations, such as receiving containers in which the incoming items are stacked, corresponding to the markings on the mail.

In general, the mail is subjected to a preliminary sorting after which the items in any given receiving container are processed through a subsequent sorting system. For example, the preliminary sorting can be used to distribute the mail according to major postal zones, whereas the subsequent sorting will sort the mail sent to each major zone into mail intended for a number of sub-zones. If this subsequent sorting process, too, is to be carried out automatically, the items will have to carry additional markings. As a result, the subsequent sorting process has to be such that it can distinguish the markings intended to control this subsequent sorting process from the markings which controlled the first sorting process.

It is conceivable that the above result may be obtained by letting the markings which control the first sorting process be of luminescent material while the markings which control the subsequent sorting process are constituted by a magnetizable material. This, however, requires the provision of different types of scanning means capable of responding to these different types of markings, to say nothing of the different types of applicator means for providing the items of mail with such different markings in the first place. These drawbacks may be avoided by using luminescent markings for controlling both the first and second sorting processes, with the markings pertaining to the first sorting process being of fluorescent material and the markings pertaining to the second sorting process being of phosphorescent material. (For the sake of clarity, it is pointed out that "luminescent markings" are intended to refer to non-incandescent markings which, though not producing any primary emission, produce a secondary emission when being illuminated; that "fluorescent markings" are luminescent markings which produce a secondary emission which is observable while the markings are actually being excited by illumination; and that "phosphorescent markings" are luminescent markings which produce a secondary emission which is still observable after the cessation of actual illumination.) Such luminenscent markings may be scanned by luminescence-responsive means, namely, by devices which respond to the secondary emission radiated by the fluorescent and phosphorescent markings, and the present invention resides in a method and apparatus for scanning both of these markings in such a manner as clearly to differentiate between the two types of markings.

2

Before proceeding with a brief description of the present invention, there will first be considered the problem encountered in differentiating between the secondary emission emanating from a fluorescent material and the secondary emission emanating from a phosphorescent material. For this purpose, reference is made to FIGURE 1 which is a plot showing the intensity I, as a function of time t, of the secondary emission of a fluorescent and a phosphorescent material which is illuminated throughout a time interval beginning at t_1 and ending at t_2. The secondary emission from the fluorescent material, indicated by the dot-dash curve a, starts at t_1 and ends immediately at t_2, whereas the secondary emission from the phosphorescent material, indicated by solid curve b, decreases gradually after the instant t_2, it having been found that curve b will follow a generally exponential function. Inasmuch as the fluorescent material produces a secondary emission only during the time interval t_1–t_2, i.e., during the time at which the material is actually being illuminated, it becomes relatively simple to recognize phosphorescent markings even though there are fluorescent markings present as well, since all that has to be done is to arrange the light-sensitive receiving means in such a manner that it responds to light only after the elapse of the time interval t_1–t_2, as for instance, during the time interval t_3–t_4 shown in FIGURE 1. One way in which this can be achieved is by placing the light-sensitive scanning device, such as a photoelectric cell, at a point "downstream" of the light source which illuminates the markings, i.e., by placing the scanning device at such a point that the items of mail will move past it after having been first illuminated by the light source.

One drawback of the above arrangement is that, while the phosphorescent markings can be distinguished from the fluorescent markings, it is not possible to distinguish the fluorescent from the phosphorescent markings. This is so because, as is apparent from FIGURE 1, both the fluorescent and phosphorescent markings will issue secondary emission during the time interval t_1–t_2 when these markings are in the process of being illuminated by the light source. One way in which this drawback could be avoided would be to use luminescent markings having different emission spectra, and to equip the light-sensitive scanning devices with appropriate filters. However, experience has shown that the loss of intensity resulting from the use of filters reduces the signal-to-noise ratio to a point where the system will not operate satisfactorily, if at all.

It is, therefore, a basic object of the present invention to provide a method and apparatus capable of differentiating between fluorescent and phosphorescent markings, and, more particularly, of distinguishing fluorescent from phosphorescent markings, which method and apparatus overcome the above-discussed drawbacks. According to the present invention, this is accomplished by relying on the fact that the rate at which the intensity of the secondary emission of illuminated fluorescent markings increases differs from the rate at which the intensity of the secondary emission of illuminated phosphorescent markings increases. Thus, the underlying principle of the present invention is that, by selecting an appropriate phosphorescent material and carrying out the measurement for the correspondingly appropriate time interval, not only the afterglow of phosphorescent material, but also the rate at which the intensity of the secondary emission emanating from this phosphorescent material increases upon illumination thereof constitutes a valuable criterion which can be used to distinguish between fluorescent and phosphorescent materials.

Additional objects and advantages of the present invention will become apparent upon consideration of the following description when taken in conjunction with the accompanying drawings in which:

FIGURE 1 is, as described above, a plot of the intensity of the secondary emission from a fluorescent and a phosphorescent material as a function of time.

FIGURES 2 and 3 are plots similar to FIGURE 1, with the abscissas being shown on an enlarged scale.

FIGURE 4 is an illustration of an item of mail carrying both fluorescent and phosphorescent markings in a given area which is to be scanned.

FIGURE 5 is a diagrammatic sectional view of a scanning device used to carry out the present invention.

FIGURES 6 and 7 are schematic block diagrams showing the circuitry usable with the scanning device of FIGURE 5.

FIGURES 8*a*, 8*b*, and 8*c*, are schematic and idealized representations showing the wave forms and amplitudes of signals appearing at various points of the circuit of FIGURE 6.

FIGURES 9*a* and 9*b* are similar representations showing the signals appearing at various points of the circuit of FIGURE 7.

Referring now to FIGURES 2 and 3 of the drawings, the dot-dash curves *a* and solid curves *b* again represent the intensity of the secondary emission issuing from fluorescent and phosphorescent markings, respectively. In the case of fluorescent materials, the secondary emission commences, for all practical purposes, as soon as the illumination starts, as shown at t_1. This is generally explained as being due to the spontaneous transition which a molecule undergoes from the excited energy state to a state of lower energy level; such transition occurs within a time interval which is generally less than 10^{-7} second. In the case of phosphorescent materials, however, at least some of the excited molecules at first assume a metastable level in which the probability of existence is substantially greater. From this level, there occurs a return, according to the principle of statistics, via the excited level, to the original level, at which time the secondary emission occurs. Accordingly, the rate at which the intensity of the secondary emission emanating from the phosphorescent material, upon illumination thereof, increases is lower than in the case of fluorescent material. Expressed graphically, the slope of curve *b* is less steep than that of curve *a*.

Thus, for carrying out the present invention, all that is necessary is that the scanning or test interval t_5–t_6 is so located and dimensioned, along the axis *t*, that the difference in the slopes of curves *a* and *b* is recognizable and capable of being translated into useful signals.

In FIGURE 2, it is assumed that the markings are illuminated throughout the time interval t_1–t_2'; this figure also shows the general case in which the test interval begins at instant t_5, whichi s earlier than t_1, and ends at t_6, which is earlier than t_2'. For the sake of clarity, the intensity-time areas of the usable secondary emissions, or the corresponding electrical signals which represent these secondary emissions, are differently hatched, depending on what they represent.

In practice, however, the instants t_1 and t_5 on the one hand, and the instants t_2' and t_6 on the other, will normally coincide, because the illumination directed toward the markings and the scanning of the luminescent markings by means of the photoelectric scanning device, will occur through the same slot. This simplified case is shown in FIGURE 3, which will also be relied on for the subsequent explanation of the invention. As in the case of FIGURE 2, the test interval lies within the ascending portion of the curve *b* representing the secondary emission of the phosphorescent material. From this, there are obtained the following electronic circuit requirements and possibilities by which the present invention can be carried out:

The signals due to the fluorescent and phosphorescent materials differ from each other insofar as the slopes of their rising flanks are concerned. In order to distinguish these signals from each other, they can be applied to a differentiating circuit at whose output there will appear signals of different amplitude which can easily be separated. (The term "differentiating circuit" or "differentiating means," as used throughout the instant specification and claims, is intended to refer to a circuit or means for producing the first derivative of a quantity.) Alternatively, the amplitudes of the two signals themselves can be used as the distinguishing characteristics, so that an appropriate separation can be effected. As yet another alternative, the areas beneath the curves and the abscissa can be determined, by integration, and the amplitude of the integral values be determined in order to distinguish between curves *a* and *b*.

FIGURE 4 shows a letter *l* carrying, within a given area **2** to be scanned, two groups of markings each consisting of four columns, each column, in turn, containing two dots to form a two-out-of-five code. The dots **3** pertaining to one group are made of fluorescent material, and the dots **4** pertaining to the other group are made of phosphorescent material. As explained above in connection with FIGURE 1, the phosphorescent code groups constituted by the dots **4** are scanned by sending the letter through a transport system which moves the letter past a light source that illuminates the code group **4** for a time interval t_1–t_2, which may be somewhat longer than shown in FIGURE 1. The letter is then, throughout a time interval t_3–t_4 (taken with reference to the individual columns), moved past a slot behind which the photoelectric scanning device is located.

FIGURE 5 shows an arrangement which can be used for scanning markings consisting of fluorescent material only. The letter is moved past a guide plate **5** which has a slot **6** of a width *d* of, for example, 4 millimeters. Behind the slot, there is a U-shaped mercury vapor lamp **7** which emits ultraviolet rays, as well as a photoelectric element **8** whose output leads are connected to the input of an amplifier **9**; the output terminals of the amplifier **9** are shown at **10** and **11**. Although but one photoelectric element **8** is shown, there will, in practice, be five such elements each arranged at the level of one of the five lines which make up the columns. Each element **8** will have its own respective amplifier, and the output of each of the amplifiers is connected to a suitable electric circuit, as will be described below. FIGURE 5 also shows filters **12** interposed between the mercury vapor lamp **7** and the slot **6**, which filters allow only ultraviolet but no visible light to pass. Also, a filter **13** is interposed between the slot **6** and each photoelectric element **8**, which filter **13** will allow only the secondary emission from the luminescent material to reach the photoelectric elements. Finally, the letter *l* is moved past the scanning device at a velocity *v*, as shown by the arrow. The means for actually moving the letter are well known in the art and are, therefore, not shown.

By applying the present invention, the scanning device of FIGURE 5 can also be used for scanning mail such as the letter *l* which carries not only fluorescent markings **3** but also phosphorescent markings **4**. It will be appreciated that all that is required is that (*a*) the width *d* of the slot **6** through which the scanning occurs, (*b*) the velocity *v* at which the letter is moved past the slot **6**, and (*c*) the characteristics of the phosphorescent material, are so selected with respect to each other that the difference in the rising slopes of curves *a* and *b* can be utilized. The factors (*a*), (*b*), and (*c*) can be matched to each other empirically.

FIGURE 6 shows a circuit which can be connected to the output terminals **10** and **11** of amplifier **9** for the purpose of allowing the secondary emission emanating from the fluorescent and phosphorescent markings, respectively, to be distinguished on the basis of their different intensity-versus-time slopes. The circuit comprises a differentiating stage **14**, an amplifier **15**, and an amplitude selection stage **16**.

FIGURE 8*a* is a plot showing the signals, represented by voltages V, appearing at the output terminals **10, 11**, of the amplifier **9** when the letter *l* moves past the slot **6**, of width *d*, at the velocity *v'*. The signals due to the fluorescent mrakings **3** are shown at **17**, the signals due to the phosphorescent markings **4** are shown at **18**. Both pulses have approximately the same duration or length $T=d/v'$. FIGURE 8*b* shows the shapes of the signals as they appear, after having been differentiated and amplified, at the output of amplifier **15** (without considering any polarity reversal). Each pulse **17** will result in a positive pulse **17'** and a negative pulse **17''**, and each pulse **18** will result in a positive pulse **18'** and a negative pulse **18''**. It will be seen that the pulses **17'** pertaining to the fluorescent markings **3** will have a different amplitude than the pulses **18'** pertaining to the phosphorescent markings **4**. The amplitude selection stage **16** will then be so designed as to let only those signals which exceed a given threshold value V_s, appear at the output terminals **19, 20**. This is shown in FIGURE 8*c*, from which it will be seen that the circuit of FIGURE 6 will produce only such output signals **17'''** as correspond to a fluorescent marking **3**.

FIGURE 8*a* also shows that, under the conditions which this figure represents, the amplitudes of signals **18** appearing at output terminals **10, 11**, and corresponding to the phosphorescent markings **4** are somewhat greater than the amplitudes of signals **17** pertaining to the fluorescent markings **3**. Let it now be assumed that the transport velocity is increased from *v'* to a higher velocity *v''*, the remaining parameters remaining unchanged. The output signals **21, 22**, appearing at terminals **10, 11**, will then have the shape and amplitude shown in FIGURE 9*a*. The pulse width $T''=d/v''$ of these pulses will be less than was the pulse width $T=d/v'$ of FIGURE 8*a*. Furthermore, the amplitude of the pulse **22** corresponding to the phosphorescent marking **4** will be less than the amplitude of the pulse **21** corresponding to the fluorescent marking **3**, due to the slower increase in intensity of the secondary emission emanating from the phosphorescent material. It is therefore possible to eliminate the differentiating stage **14** and to submit the output of amplifier **9** immediately to an amplitude selection. Such an arrangement is shown in FIGURE 7, which includes only the amplifier **15** and an amplitude selection stage **16'** which is so designed as to pass only those signals which exceed a given threshold value V_s'. Consequently, the signals appearing at the output terminals **23, 24** of the amplitude selection stage **16'** will, as shown in FIGURE 9*b*, include only pulses **21'** which correspond to the fluorescent markings **3**.

Instead of increasing the velocity *v*, similar results can be obtained if the width *d* of the slot **6** is decreased, or if, instead of the original phosphorescent material, a different phosphorescent material having a slower rate of secondary emission intensity increase is used. In practice, the use of the arrangement shown in FIGURE 7 will be limited to circumstances when the output of the photoelectric element **8** has a sufficiently high signal-to-noise ratio.

Suitable phosphorescent materials which may be used and which produce the necessary curve *b* are, for example, a matter which is known as Perhydrocoronene or another matter known commercially as "Lettalite." Both of them are organic substances and generally it has been found up to now that the phosphors which have been especially suitable for the requirements of the invention are chemically of organic structure.

In a practical embodiment of the invention according to FIGURES 5, 7, 9*a* and 9*b* the width of the slot **6** was $d=2.5$ millimeters, the velocity at which the letters were moved past the slot was 2.5 meters per second, the phosphorescent markings **4** were composed of "Lettalite" and the fluorescent markings **3** contained a pigment known commercially as "Lumogen UV gelb-orange."

The circumstances as concerning the form and amplitude of the signals illustrated in FIGURE 8*a* may occur if for instance a slot **6** of a width $d=15$ millimeters and a passing velocity of $v'=1$ meter per second is used, the phosphorescent markings **4** are composed of "Lettalite" and rather tenuous transparent markings **3** of "Lumogen UV gelb-orange" are employed, and if these markings are applied to letters having a comparatively dark surface.

It will be well understood that the circuitry of FIGURE 7 is practical only if signal ratios such as illustrated in FIGURE 9*a* are available, whereas the circuit of FIGURE 6 is applicable under the conditions shown in FIGURE 8*a* as well as in FIGURE 9*a*.

It will further be understood that the above description of the present invention is susceptible to various modifications, changes, and adaptations, and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

What is claimed is:

1. An apparatus capable of distinguishing between fluorescent and phosphorescent markings, comprising, in combination:
   (*a*) means for illuminating the markings; and
   (*b*) detector means responsive to the secondary emission emanating from the markings for producing signals only if the rate at which the intensity of such secondary emission emanating from the markings, upon illumination thereof, increases, exceeds a predetermined rate.

2. An apparatus as defined in claim 1 wherein said signal producing means comprise:
   (1) a photosensitive means responsive to secondary emission emanating from the markings;
   (2) a differentiating means having its input connected to the output of said photosensitive means; and
   (3) an amplitude selection means having its input connected to the output of said differentiating means.

3. An apparatus as defined in claim 1 wherein said signal producing means comprise:
   (1) a photosensitive means responsive to secondary emission emanating from the markings; and
   (2) an amplitude selection means having its input connected to the output of said photosensitive means.

4. An apparatus capable of distinguishing fluorescent from phosphorescent markings, comprising, in combination:
   (*a*) means for illuminating said markings;
   (*b*) detector means responsive to the secondary emission emanating from the markings for producing signals which bear a relationship to the rate at which the intensity of such secondary emission emanating from the markings, upon illumination thereof, increases; and
   (*c*) means for separating the signals due to secondary emissions which increase at a rate higher than a

predetermined threshold rate from the signals due to secondary emissions which increase at a rate that is not higher than said threshold rate, whereby signals pertaining to fluorescent markings may be distinguished from signals pertaining to phosphorescent markings.

5. An apparatus for scanning articles bearing both fluorescent and phosphorescent markings and capable of distinguishing between these two types of markings, said apparatus comprising, in combination:

(*a*) means for exposing each marking to exciting rays;

(*b*) detector means for deriving from said markings, due to their secondary emission, electric signals which bear a relationship to the rate at which the intensity of secondary emissions emanating from the markings, upon excitation thereof, increases; and

(*c*) means for separating the signals due to secondary emissions which increase at a rate higher than a predetermined threshold rate from the signals due to secondary emissions which increase at a rate that is not higher than said threshold rate, whereby signals pertaining to fluorescent markings may be distinguished from signals pertaining to phosphorescent markings.

6. An apparatus for scanning articles bearing both fluorescent and phosphorescent markings and capable of distinguishing between these two types of markings, said apparatus comprising, in combination:

(*a*) means for exposing each marking to exciting rays;

(*b*) photosensitive detector means for converting the secondary emission emanating from the markings, upon excitation thereof, into an electric signal;

(*c*) differentiating means having an input connected to the output of said photosensitive means for producing an output signal the amplitude of which is related to the rate of change of the output of the photosensitive means; and

(*d*) amplitude selection means conected to said converting means for separating the signals the amplitude

of which exceeds a predetermined threshold amplitude from the signals the amplitude of which does not exceed said threshold, said threshold being such as to separate signals pertaining to fluorescent markings from signals pertaining to phosphorescent markings.

7. An apparatus for scanning articles bearing both fluorescent and phosphorescent markings and capable of distinguishing between these two types of markings, said apparatus comprising, in combination:

(*a*) means for exposing each marking to a pulse of exciting rays during a predetermined first interval;

(*b*) detector means for converting the pulse of secondary emission emanating from the markings upon excitation thereof into an electric signal pulse during a second interval, said first and said second interval being selected to allow evaluation of an essential part of the leading edge of an electric signal pulse resulting from the secondary emission of a phosphorescent marking; and

(*c*) amplitude selection means connected to said converting means for separating the signals the amplitude of which exceeds a predetermined threshold amplitude from the signals the amplitude of which, in view of said intervals, does not exceed said threshold, said threshold being such as to separate signals pertaining to fluorescent markings from signals pertaining to phosphorescent markings.

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