

Dec. 5, 1950

C. F. ROBINSON
SORTING APPARATUS

2,532,644

Filed Feb. 18, 1949

2 Sheets-Sheet 1

FIG. 1.

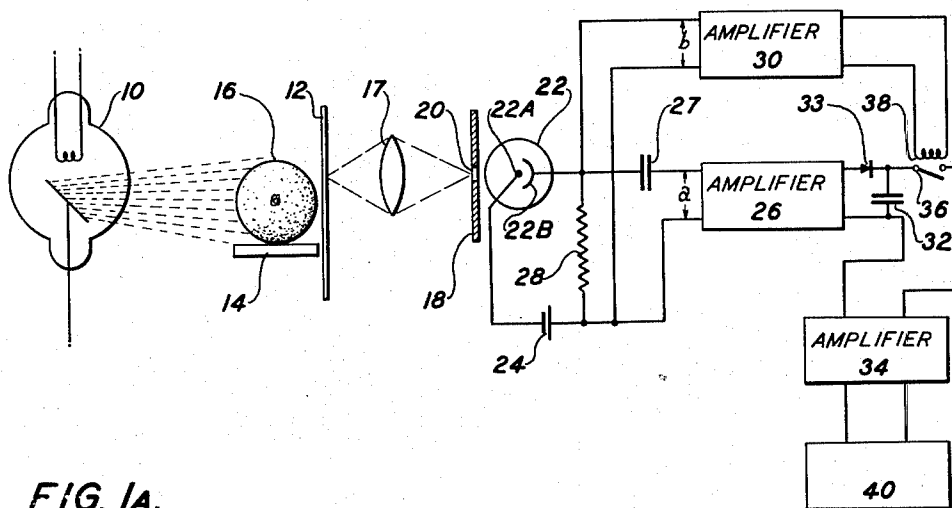


FIG. 1A.

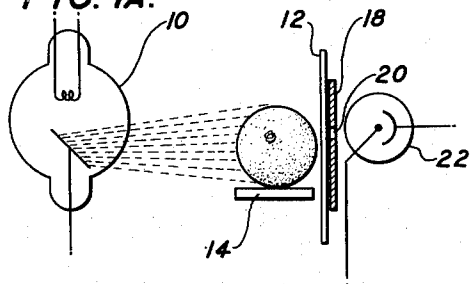
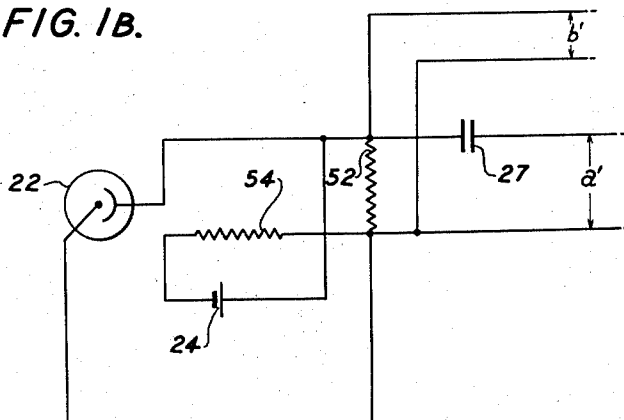


FIG. 1B.



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2 Sheets-Sheet 2

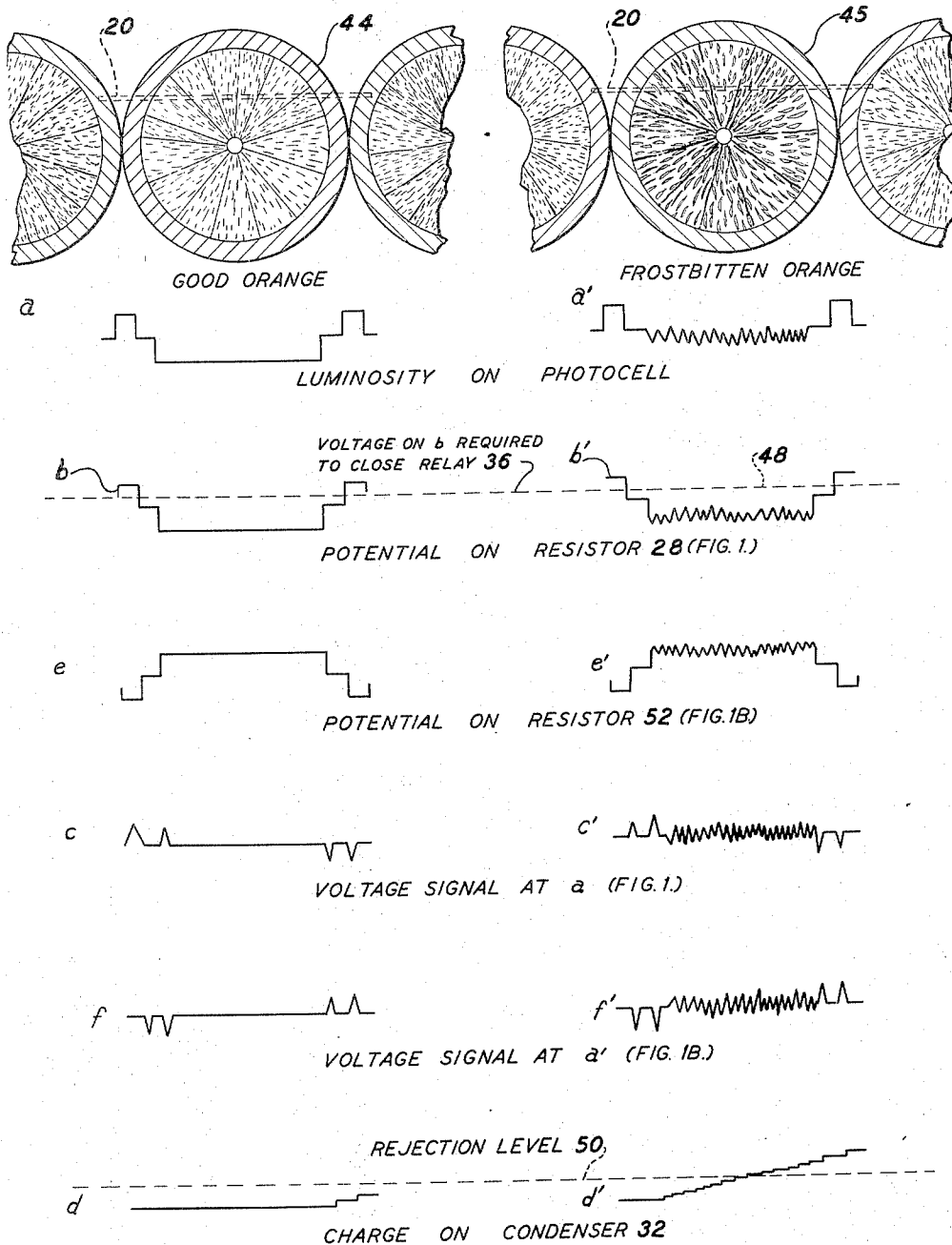


FIG. 2.

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SORTING APPARATUS

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18 Claims. (Cl. 250—52)

1

This invention relates to a method and apparatus for automatically discriminating between articles on the basis of the uniformity or non-uniformity of their transparency to X-rays and selective segregation based on such discrimination.

The invention finds particular application in food processing and handling and may be applied in any application where it is desired to discriminate between articles having on the one hand, uniform X-ray transparency or X-ray transparency having a number of local variations, or X-ray transparency which does not vary sharply between one position and another, and articles on the other hand, which show large numbers of non-uniformities or sharp variations in X-ray transparency. Thus the apparatus may be used to make selection between objects of the same kind which for one reason or another may vary in uniformity of X-ray transparency from object to object. In the alternative, selection may be made between commingled objects of different kinds which are characterized by differences in their X-ray transparency pattern.

A particularly fertile field for apparatus of this character is in the citrus packing industry. Accordingly, the invention is described and illustrated with reference to its use in this industry to sort citrus fruit prior to packing. Selection of a single industry for purposes of description is made for purposes of convenience only, the invention being equally applicable to all situations wherein the above conditions with respect to X-ray transparency are encountered.

It is well known that citrus fruits in general are susceptible to damage from exposure to sub-freezing temperatures. The damage consists of changes in the structure of the internal tissue of the fruit imparting thereto a dry, pithy or granular structure as compared with the juicy, almost uniform density structure of an undamaged fruit. Additionally, citrus fruit is subject to so-called "granulation" apart from change due to frostbite which results in a tissue deterioration and structure quite similar to that produced by frostbite. At the present time there does not appear to be any conclusive explanation of the cause of such granulation. In any case, it is known to occur and it becomes necessary to separate granulated fruit as well as frostbitten fruit from good fruit before the latter is marketed. Hereafter the term "granulated" will be used to describe frostbitten as well as granulated fruit, since it is descriptive of the tissue structure resulting from either cause.

2

This separation of granulated fruit from good fruit is complicated by the fact that the change in internal tissue structure is not accompanied by any detectable change in outer appearance. It has been found in the case of frostbite, that if sufficiently severe, there will be such a change in the density of the fruit that it becomes separable from good fruit by flotation. However, frostbite less severe than that necessary to permit a separation by flotation will still damage the fruit to the extent that it is not marketable except for preparation of by-products.

Because oranges are of primary economic importance, the following description relates to their separation. However, the same considerations and procedures are equally applicable to all of the citrus fruits as well as other products.

It is known that granulated oranges may be distinguished from those not so damaged by examination with transmitted X-rays. Ordinarily, oranges have an X-ray transparency image characterized by a central absorbent portion corresponding to the meat of the orange surrounded by a less absorbent region corresponding to the more or less pithy rind. The center absorbent portion in a good orange shows little evidence on X-ray examination, of internal structure due to only slight variation in transparency throughout the central portion, while the same portion in a frostbitten orange shows an irregular, mottled or granular appearance due to sharp variations in X-ray transparency throughout the central portion.

The use of X-rays for grading oranges on the basis of their internal structure has become a common practice in the citrus packing industry. However, X-ray application as currently employed requires a final rejection of damaged oranges to be made by a human operator on the basis of the overall appearance of the orange when viewed by transmitted X-ray. As a result an error factor is introduced based on operator fatigue, misjudgment and occasional oversights. Furthermore, the presence of a human operator necessitates elaborate electrical and X-ray shielding for reasons of safety. Consequently, it is desirable that means be provided for adapting X-ray examination to completely automatic operation since more accuracy and reduced costs will be the result. Such an automatic apparatus is more economical than existing apparatus for reasons mentioned above and for the further reason that an automatic device can be made to work continuously and with greater rapidity than apparatus depending upon a human operator.

For example, in one packing plant in the Southern California area it has been found necessary to keep the present non-automatic X-ray equipment in operation 24 hours a day in order to keep the packing plant on an eight hour production schedule.

I have now invented a method and apparatus for distinguishing continuously and automatically between sound oranges on the one hand and oranges which have been frostbitten or have granulated on the other and which may be applied without material changes to any commercial grading problem in which the articles to be graded are distinguishable one from the other by differences in the uniformity of their transparency to X-rays.

In one embodiment, the apparatus of the invention comprises a source of X-rays, a fluorescent body, means for successively disposing oranges, or other articles between the source and the fluorescent body, a photo-electric cell adapted to develop a potential responsive to the light intensity on a small area of the fluorescent body, means for moving each orange past this area, electrical means for charging a condenser in proportion to the variations in potential development by the photocell, and means for applying the potential thus impressed on the condenser to reject those oranges of non-uniform transparency.

Other embodiments of the invention include additional refinements, but all of these likewise operate on the basic principle that a condenser is charged responsive to variation in X-ray transparency throughout each orange. In this fashion the oranges of substantially uniform transparency do not develop an appreciable charge on the condenser whereas the oranges of non-uniform transparency produce a considerably larger charge on the condenser. It is this larger charge which is used, in accordance with the invention, to operate an electrically actuated rejection mechanism.

A feature of the invention is the application of a photocell to replace the visual scanning of the fluorescent screen. Visual examination requires that the X-ray equipment be operated at high intensity necessitating expensive equipment with a high depreciation factor. However, by employing the more sensitive photo-electric cell, lower intensity and thus lower cost X-ray apparatus may be employed.

Another feature of the invention is that its application is based on non-uniformity of X-ray transparency within a single object instead of between two objects. For example, given two oranges of different and yet uniform X-ray transparency, neither would be rejected. However, sharp variations of transparency within a single orange will produce a comparatively large charge on the aforementioned condenser which upon discharge will actuate the rejection device to discard the orange.

The invention will be clear from the following detailed description taken in relation to the accompanying drawings in which:

Fig. 1 shows one embodiment of the invention in diagram form;

Fig. 1A shows an alternative arrangement of the fluorescent screen and photocell;

Fig. 1B shows an alternative form of electrical circuit wherein the effect of variations in light intensity on the photocell is just opposite to that in the apparatus of Fig. 1; and

Fig. 2 is a graphical portrayal of the conditions which prevail in the various parts of the

apparatus of Fig. 1 and Fig. 1B when a sound orange and when a frostbitten orange are subjected to the X-ray examination.

Referring to Fig. 1, the apparatus there shown includes a source 10 of X-rays, the source being illustrated as a conventional X-ray tube, a fluorescent screen 12 spaced from the source 10 and on the opposite side of a conveyor 14. The conveyor forms no part of the present invention other than its necessary relationship thereto in carrying oranges 16 between the X-ray source 10 and the fluorescent screen 12. A lens 17 is spaced from the fluorescent screen 12 a distance greater than the focal length of the lens and on the opposite side of the screen 12 from the X-ray source 10. An opaque screen 18 is spaced on the opposite side of the lens 17 at such a distance as to make the fluorescent screen 12 and the opaque screen 18 essentially at conjugate foci of the lens 17, the screen 18 having an aperture 20 therein. A photocell 22 is disposed behind the aperture 20 to receive the transmitted light from the fluorescent screen 12 as picked up and focused by the lens 17.

Anode 22A of photocell 22 is connected through a battery or other D. C. source 24 to an amplifier 26. Cathode 22B of the photocell is connected through a condenser 27 to the amplifier 26. A resistor 28 is connected across the anode and cathode and a second amplifier 30 is connected across the resistance 28. A condenser 32 is connected across the output of amplifier 26 through a rectifier 33. A third amplifier 34 is connected across the condenser 32 through a relay 36, coil 38 of which is connected across the output of amplifier 30. A rejection device 40 is connected to the output of amplifier 34.

The amplifier 34 is an optional feature and in many cases may be replaced by an electrical relay of appropriate sensitivity or by an electron tube of the thyatron type. Alternatively, and if the charge of condenser 32 is sufficiently large, the rejection device 40 may be connected directly across the condenser 32 without intermediate amplification or triggering means.

The operation of the apparatus of Fig. 1 can best be described in relation to Fig. 2 which is a graphical portrayal of the conditions existing in various parts of the apparatus of Fig. 1 during the operation thereof. There is shown in Fig. 2 a good orange 44 and a frostbitten orange 45 with the position of the scanning aperture 20 with respect to the oranges shown by dotted lines across the face of the orange. Directly below oranges 44, 45 there is shown in graphs *a* and *a'* respectively, the fluorescent luminosity on the photoelectric cell 22, when the oranges 44, 45 are scanned along the line of aperture 20. These graphs illustrate the initial high luminosity when the space between one orange and the next is scanned, the lower luminosity when the X-ray beam is partially absorbed in the skin of the orange, and the still lower luminosity when the X-ray beam is still more completely absorbed in the watery meat of the orange. From the graphs *a*, *a'* it will be observed that the highest absorption both in the sound orange 44 and the frostbitten orange 45 is in the central meaty portion of the orange and that in the case of the sound orange the absorption is practically constant throughout this portion whereas in the frostbitten or granulated orange the absorption fluctuates sharply.

Referring to Fig. 1, the luminosity on the photo-electric cell is translated to an electric potential on resistor 28 in such a fashion that

an increase in luminosity on the photocell results in an increase in voltage on the resistor. The potential developed across resistor 28 for a good orange and for a frostbitten orange are shown in graphs *b* and *b'* respectively, of Fig. 2 in relation to the degree of luminosity represented by graphs *a* and *a'*. A dotted line 48 intersecting the graphs *b*, *b'* is representative of the voltage required to close the relay 36 in the manner hereinafter described. Thus, the potential on resistor 28 reaches a value sufficiently high to actuate relay 36 only when there is no, or substantially no X-ray absorption between the source and the fluorescent screen; i. e. in between succeeding objects.

The voltage across resistor 28 is fed through condenser 27 to the amplifier 26. The effect of the condenser 27 is to pass to the amplifier 26 only the alternating component of the voltage across resistor 28, i. e. only that voltage developed responsive to changes in X-ray transparency. Graphs *c* and *c'* show the signal voltage delivered to the point *a* in Fig. 1, i. e. the input of the amplifier 26. It will be noted that the graph *c* representing the input voltage developed by passage of the sound orange 44 between the X-ray tube and the fluorescent screen is a straight line across the central portion of the orange, this being due to the fact that there is substantially no alternating component developed in scanning the sound orange. On the other hand, the voltage signal delivered to the amplifier 26 during the period a frostbitten orange is being scanned (see graph *c'*) varies sharply across the central portion of the orange correlative to the variations in transparency illustrated in graph *a'*.

As the orange passes across the field of view of the optical system, the amplifier 26 delivers a pulse or charge to condenser 32 through the rectifier 33 every time there is an appreciable change in the X-ray transparency. A great variety of electrical systems well known in the art may be employed to cause amplifier 26 to deliver a charge or pulse to the condenser only when a sudden change of voltage across resistance 28 takes place, only when a more gradual change takes place, or both. One means of accomplishing this is shown in Fig. 1.

In scanning the sound orange 44 (Fig. 2), the system will show only a comparatively small number of gradual changes in luminosity and consequently the charge delivered to condenser 32 will be substantially negligible and its potential correspondingly small. The build up of a charge on condenser 32 during the scanning of the sound orange 44 is shown by graph *d* of Fig. 2 where it will be noted that substantially no charge is built up during the scanning of the central meaty portion of the orange. If a frostbitten orange is scanned there is a materially greater number of changes in transparency as represented by graph *a'* (Fig. 2) with a correspondingly greater charge delivered to condenser 32 and a higher potential on the condenser at the end of the scanning operation. The build up of a charge on condenser 32 during the scanning of the frostbitten orange 45 is illustrated in the graph *d'* of Fig. 2.

If it is desired that the system be responsive both to magnitude and to number of variations in X-ray transparency, amplifier 26 should be of non-saturating type. If it is desired that the system sense only on number of variations without regard to their relative magnitudes, amplifier 26 may have high inherent gain but saturate at

a relatively low output level. If it is desired that the system be responsive only to variations larger than a given magnitude, this may be accomplished by inserting a fixed D. C. bias in rectifier 33 or in a variety of other ways obvious to those skilled in the art. All these embodiments, which may be desirable to meet the needs of specific problems, will be obvious to those skilled in the electronic art from the essential bases of the invention here disclosed.

As soon as the scanning of a single object is complete the light level on the photocell returns to the high value corresponding to the absence of an X-ray absorber in the path of the X-ray beams. This high value is represented on the extremities of graphs *a*, *a'*, of Fig. 2. This high light level causes the potential across resistor 28 to rise to its maximum value (in the circuit arrangement of Fig. 1) whereupon amplifier 30 delivers a current to the coil 38 of relay 36 to close the relay. When the relay 36 is thus closed the charge accumulated on condenser 36 is impressed on the rejection device 40 through the intermediate amplifier 34. As stated above, this amplifier may be eliminated if desired. If the oranges are frostbitten, condenser 32 has a large enough charge to operate rejection device 40, whereas if the orange is sound there is not a sufficient charge built up on condenser 32 to operate the rejection device. This is shown in graphs *d* and *d'* of Fig. 2 wherein the rejection level is shown by the dotted line 50 traversing the graphs. It is seen that the charge built upon the condenser 32 for the frosted orange 45 exceeds the rejection level 50 of the rejection device 40 whereas the build up for the orange 44 falls short of that necessary to operate the rejection device.

In either case, i. e. whether or not the rejection device is operated, the charge on condenser 32 is discharged and the appearance of the next object to be examined produces such a drop in potential across the resistor 28 that relay 36 is de-energized whereby the system is ready to repeat the cycle.

Modifications of the apparatus of Fig. 1 are shown in Figs. 1A and 1B. Fig. 1A shows apparatus substantially similar to that of Fig. 1 including the X-ray tube 10, fluorescent screen 12, opaque screen 18 and photocell 22. The apparatus of Fig. 1A differs from that of Fig. 1 in the elimination of lens 17 and placement of the opaque screen 18 directly behind the fluorescent screen 12. This represents simplified apparatus which occupies less physical space than that of Fig. 1 and which is less expensive than that of Fig. 1.

The same object may be accomplished in the same manner by eliminating both the fluorescent and the opaque screens and using a single spot of fluorescent material to accomplish the same effect. In any case, the essential object of the screen system is that at any instant the photoelectric cell shall be sensitive to the X-ray absorption of only a restricted part of the whole object to be examined and that during transport of the object across the scanning field, the photo-electric cell shall sense on a consecution of such restricted parts. The several parts of the objects scanned may form all or less than all of the whole object depending upon the nature of the specific problem.

In the application of the apparatus to the discrimination between sound and granulated or frostbitten oranges, it is desirable that the resolving power of the system be high since the characteristics to be examined are of fine structure.

Accordingly, in the apparatus of either Figs. 1 or 2 the total of separate parts scanned forms a narrow strip as the orange moves past the aperture 20 in the opaque screen.

However, if desired, the apparatus may include means for scanning the entire object part by part. This may be done by replacing the opaque screen with a scanning disc which is rotated as the object crosses the field of view. Such a scanning disc may be generally circular with an aperture therein and may be rotated at such a rate with relation to the rate of linear travel of the object to be examined that a plurality of strips across the object are scanned. Essentially, this amounts to having the aperture 20 in the opaque screen move in a direction more or less transverse to the direction of the object so that instead of scanning a single horizontal strip as shown in Fig. 2, a succession of vertical strips is scanned, the number being dependent upon the rate of rotation of the scanning disc as related to the other factors involved.

The scanning of the entire object part by part may also be accomplished by electronic means so as to eliminate the mechanical scanning disc described above. Thus, a pickup or camera tube such as an image orthicon may be incorporated in the apparatus to replace the optical system and photoelectric cell and in such fashion that it scans the fluorescent screen. The output of the camera tube is connected in the circuit in the same manner as the photo-electric cell 22 to develop a potential on the resistor 23 responsive to change in X-ray transparency of the object.

Fig. 1B shows a circuit modification of the apparatus of Fig. 1 wherein the effect of changes in light level on the photocell 22 has the opposite effect on the voltage signal delivered to a' and b' , i. e. to amplifiers 26 and 30 (not shown in Fig. 1B). In the circuit arrangement of Fig. 1B a resistor 52 is connected across the output of the photocell and corresponds generally to the resistor 23 in Fig. 1. The battery or D. C. source 24 is likewise connected across the output of the photocell through an additional resistor 54 so that an increase in light intensity on the photocell 22 will result in a decrease in potential developed across resistor 52, thus, having an opposite effect than that occurring in Fig. 1.

Graphs e, e' of Fig. 2 show the potential changes on resistor 52 corresponding to the luminosity changes shown in graphs a and a' , and it will be noted that the graphs e and e' are substantially the reverse of the graphs b and b' which show the potential changes on resistor 23 (of the apparatus of Fig. 1). Similarly, graphs f and f' show the voltage signal developed at a' in the apparatus of Fig. 2. Comparison of the graphs f and f' with the graphs c and c' , the latter portraying the voltage signal delivered to a of Fig. 1, shows that substantially the reverse situation exists. There is no difference in the results obtained by the apparatus of either Fig. 1 or Fig. 1B, the choice between the one or the other of the two embodiments depending solely on the phasing and polarity which is most conveniently employed in the amplifiers 26 and 30.

Amplifier 30 may be of conventional type but is most conveniently a trigger tube operating the relay 36 when the potential across resistor 23 rises above a certain predetermined level. In such embodiment, the amplifier 30 may be more accurately described as a voltage-actuated triggering circuit. Amplifier 26 is also conveniently a trigger circuit which operates to deliver a pulse

to the condenser 32 each time a signal is impressed thereon from the condenser 27. However, it is obvious that a more elaborate amplifier may be employed to accomplish the same purpose without changing the actual functioning of the apparatus and within the scope of the invention.

The rejection device 40 may consist simply of an electrically operated solenoid or paddle mounted adjacent the conveyor on the downstream side of the fluorescent screen. The location of the rejection device is necessarily synchronized with the rate of travel of the conveyor so that when it is actuated by discharge of a sufficient charge from the condenser 32 it will operate to push or pull the defective orange out of the path taken by the oranges not so rejected. The rejection device may operate directly or with the aid of gravity. It is to be understood that the rejection device as such does not form any part of the present invention other than in its relationship to the means shown for automatically operating the same. Thus, any of the conventional rejection devices now operated by manual actuation may be adapted to electrical actuation and employed in the operation of the invention.

It is apparent that since the invention is predicated on changes in X-ray transparency within a single object, there need be no uniformity between succeeding objects providing they are all characterized by a substantially uniform or non-uniform X-ray transparency. Thus the methods and apparatus described herein are suitable for rejecting frostbitten citrus fruit from good citrus fruit even where there is a mixture of oranges, lemons or grapefruit, since all of these are characterized normally by a more or less uniform transparency to X-rays. The difficulty of making such segregation from a quantity of mixed citrus fruit by visual inspection of the X-ray pattern is apparent.

Other modifications of the methods and apparatus of the invention may occur to those skilled in the art without departing from the scope thereof as set forth in the foregoing description and in the following claims.

I claim:

1. A method for automatically selecting between a plurality of objects based on the X-ray transparency characteristics of each object which comprises detecting relative variations in X-ray transparency from part to part of each object and segregating the objects on the basis of uniformity and non-uniformity of X-ray transparency between different parts of each object.

2. A method for automatically separating granulated and frostbitten citrus fruit from citrus fruit not so damaged based on the X-ray transparency characteristics from part to part of each fruit, which comprises scanning a plurality of separate portions of each fruit with X-rays and rejecting those fruit which have a non-uniform X-ray transparency from portion to portion.

3. A method for automatically selecting between two or more objects on the basis of X-ray transparency characteristics of each object which comprises subjecting each object to X-rays, developing a potential proportional to the X-ray transparency characteristics from part to part of each object, and employing changes in the potential developed responsive to said plurality of parts to operate means for separating an object possessing such non-uniformity from the other objects.

4. Apparatus for automatically selecting be-

tween a plurality of objects based on the X-ray transparency characteristics thereof which comprises a source of X-rays, means for successively subjecting each of said objects to the X-rays, means for translating changes in transparency from part to part of each object into an electrical value, and means for selecting between the objects on the basis of this electrical value.

5. Apparatus for automatically selecting between a plurality of objects based on the X-ray transparency characteristics thereof which comprises a source of X-rays, means for successively subjecting each of said objects to the X-rays, means for translating changes in transparency from part to part of each object into a D. C. potential, a condenser, means for applying said potential to the condenser so as to build up a charge on the condenser proportional to the variation in X-ray transparency between different parts of the same object, and means for selecting between the objects on the basis of the charges built up on said condenser responsive to the X-ray examination of each object.

6. Apparatus according to claim 5 wherein the means for selecting between the objects comprises an electrically actuated rejection mechanism connected across the condenser and actuated by discharge of the condenser when the charge thereon is above a predetermined value.

7. Apparatus for automatically selecting between a plurality of objects based on the X-ray transparency characteristics of each object which comprises a source of X-rays, means for successively scanning each of said objects with the X-rays, means for translating changes in transparency from part to part of each object into a D. C. potential, a condenser, means for applying said potential to the condenser so as to build up a charge on the condenser proportional to the variation in X-ray transparency between different parts of the same object, means for selecting between the objects on the basis of the charges built up on said condenser responsive to the X-ray examination of each object, and means for automatically discharging the condenser after each object is scanned.

8. Apparatus for automatically selecting between a plurality of objects based on the X-ray transparency characteristics of each object which comprises a source of X-rays, means for successively scanning each of said objects with the X-rays, a fluorescent screen disposed so that said objects pass between the X-ray source and the screen, means for translating changes in light intensity in the screen due to variations in X-ray transparency from part to part of the object into a D. C. potential, a condenser, means for applying said potential to the condenser so as to build up a charge on the condenser proportional to the variation in X-ray transparency between different parts of the same object, and means for selecting between the objects on the basis of the charges built up on said condenser responsive to the X-ray examination of each object.

9. Apparatus for automatically selecting between a plurality of objects based on the X-ray transparency characteristics of each object which comprises a source of X-rays, a fluorescent screen, means for successively carrying the objects between the X-ray source and the screen, a photocell adapted to receive light from the fluorescent screen, means for restricting the area of the fluorescent screen on which the photocell senses at any instant to less than the area of the object being scanned, electrical means connected to the

photocell for developing a D. C. potential responsive to changes in the light intensity detected by said photocell and resulting from variations in X-ray transparency from part to part of the object, a condenser connected to said electrical means so that a charge will build up on the condenser proportional to the variation in X-ray transparency between different parts of the same object, and means operable responsive to discharge of said condenser for selecting between the objects on the basis of the charges built up on said condenser responsive to the X-ray examination of each object.

10. Apparatus according to claim 9 wherein the means for restricting the area of the fluorescent screen on which the photocell senses comprises an opaque screen and an aperture in the opaque screen in a line between the fluorescent screen and the photocell, the aperture being smaller in area than the object being scanned.

11. Apparatus for selecting between a plurality of objects on the basis of the X-ray transparency characteristics thereof which comprises a source of X-radiation, a fluorescent screen, means for separately interposing a plurality of parts of each of said objects between the source of X-radiation and the fluorescent source, a photocell sensitive to the intensity of the light developed on the screen, a first amplifier connected to the photocell to receive a signal responsive to changes in the intensity of light falling on the photocell, a rectifier, a condenser connected through said rectifier across the output of the first amplifier, a second amplifier connected to the photocell, a relay connected to the condenser and having a coil connected across the output of the second amplifier, the second amplifier operating to close the relay and discharge the condenser when there is substantially no absorption of X-rays between the source and the screen, and means for selecting between the objects on the basis of the size of the charge discharged from said condenser.

12. Apparatus for selecting between a plurality of objects on the basis of the X-ray transparency characteristics thereof which comprises a source of X-radiation, a fluorescent screen, means for separately interposing a plurality of parts of each of said objects between the source of X-radiation and the fluorescent screen, a photocell sensitive to the intensity of the light developed on the screen, means for restricting the area of the screen exposed to the photocell, a first amplifier connected to the photocell to receive a signal responsive to changes in the intensity of light falling on the photocell, a rectifier, a condenser connected through said rectifier to said first amplifier, a second amplifier connected to the photocell, a relay connected to the condenser and having a coil connected across the output of the second amplifier, the second amplifier operating to close the relay and discharge the condenser when there is substantially no absorption of X-rays between the source and the screen, and means for selecting between the objects on the basis of the size of the charge discharged from said condenser.

13. Apparatus for selecting between a plurality of objects on the basis of the X-ray transparency characteristics thereof which comprises a source of X-radiation, a fluorescent screen, means for separately interposing a plurality of parts of each of said objects between the source of X-radiation and the fluorescent source, a photocell sensitive to the intensity of the light developed on the screen, a resistance connected to the anode and cathode of the photocell through a source of D. C.

11

potential, a first amplifier connected to the resistance through a first condenser to receive the A. C. component of the potential developed across the resistance responsive to the intensity of light falling on the photocell, a rectifier across the output of the first amplifier, a second amplifier connected across the resistance, a relay having contacts connected to the second condenser and an operating coil connected across the output of the second amplifier, the second amplifier operating to close the relay and discharge the condenser when there is substantially no absorption of X-rays between the source and the screen, and means for selecting between the objects on the basis of the size of the charge discharged from said condenser.

14. Apparatus for selecting between a plurality of objects on the basis of the X-ray transparency characteristics thereof which comprises a source of X-radiation, means for separately interposing a plurality of parts of each of said objects in the path of said X-radiation, conversion means for converting the X-radiation passing through said object into an electrical potential proportional to the intensity of the unabsorbed X-radiation, a first amplifier connected to said last named means to receive only the A. C. component of said potential, a rectifier, a condenser connected through said rectifier across the output of the first amplifier, a second amplifier connected to said conversion means, a relay connected across the condenser and having an actuating coil connected across the output of the second amplifier, the second amplifier operating to close the relay and discharge the condenser when there is substantially no absorption of X-rays between the source and said conversion means, and means for selecting between the objects on the basis of the size of the charge discharged from said condenser.

15. Apparatus for selecting between a plurality of objects on the basis of the X-ray transparency characteristics thereof which comprises a source of X-radiation, a fluorescent screen, means for separately interposing a plurality of parts of each of said objects between the source of X-radiation and the fluorescent source, a photocell sensitive to the intensity of the light developed on the screen, an opaque screen interposed between the fluorescent screen and the photocell and having an aperture therein of smaller area than that of said object, a first amplifier connected to the photocell to receive a signal responsive to changes in the intensity of light falling on the photocell, a rectifier, a condenser connected through said rectifier across the output of the first amplifier, a second amplifier connected to the photocell, a relay connected to the condenser and having a coil

12

connected across the output of the second amplifier, the second amplifier operating to close the relay and discharge the condenser when there is substantially no absorption of X-rays between the source and the screen, and means for selecting between the objects on the basis of the size of the charge discharged from said condenser.

16. In sorting objects, the improvement which comprises passing X-rays through a plurality of separate portions of each object, sensing variations in X-ray transparency between said portions, and separating those objects in which the total of said variations exceeds a predetermined magnitude from those objects in which the total of said variations falls short of said predetermined magnitude.

17. In sorting objects, the improvement which comprises passing X-rays through a plurality of separate portions of each object, developing a potential responsive to variations in X-ray transmission between said portions, charging a condenser with said potential and differentiating between the objects on the basis of relative condenser charges.

18. Apparatus for selecting between a plurality of objects based on the radiation transparency characteristics of the individual objects, comprising a source of radiation to which the objects are at least partially transparent, means for successively subjecting the objects to radiation emanating from said source, means for translating radiation transmitted through a plurality of parts of each object into an electrical signal, means for differentiating said signal, an amplifier for amplifying the differentiated signal, and means for integrating the output signals of the amplifier separately for each object, the arrangement being such that the several objects are characterized by the magnitude of the integrated amplifier output signals separately derived from each object.

CHARLES F. ROBINSON.

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