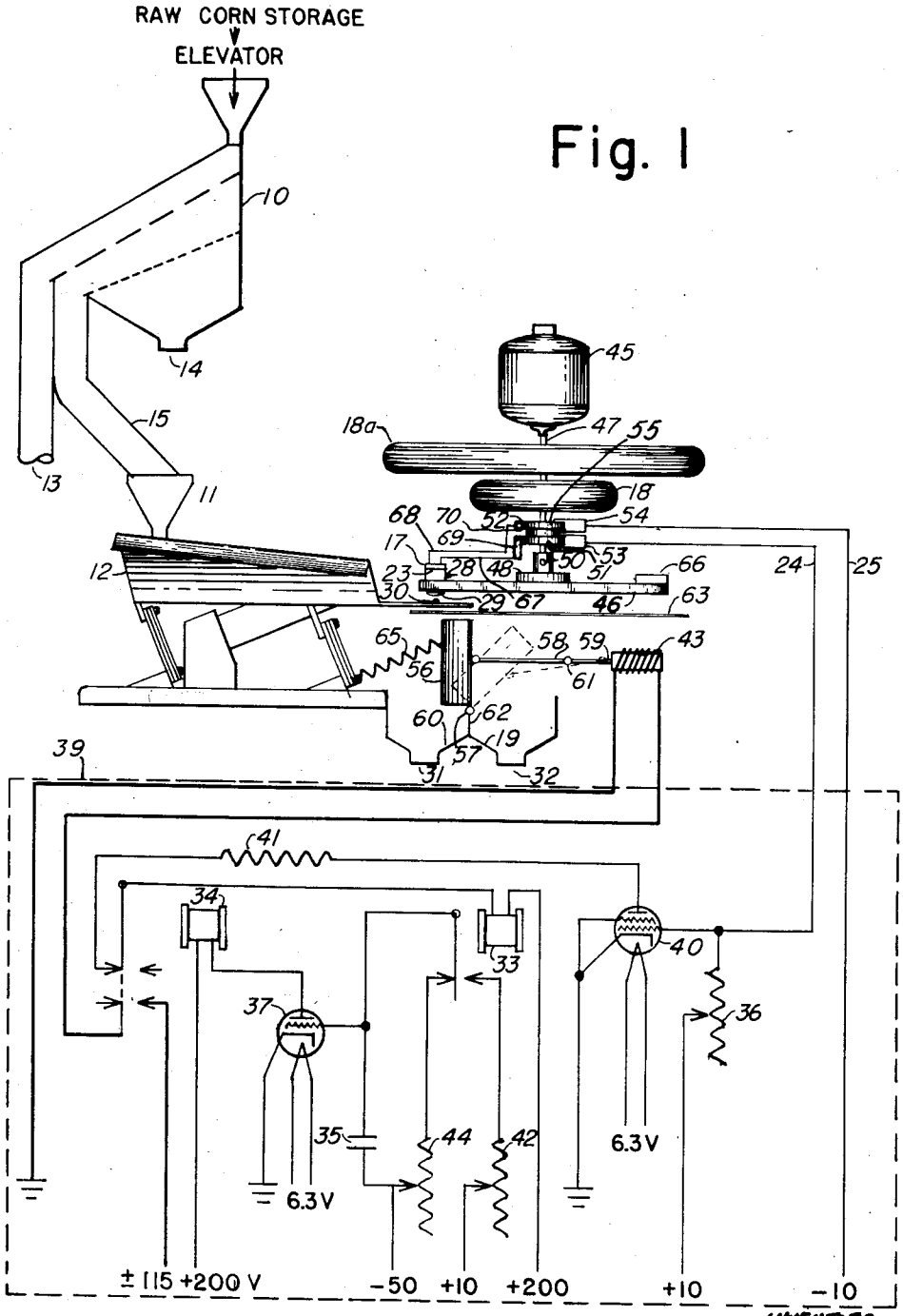
May 24, 1960 F. C. WOHLRABE ET AL 2,937,750

COLOR SEPARATION PROCESS AND APPARATUS FOR THE REMOVAL OF IMPURITIES FROM WHOLE CORN KERNELS

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Fig. 1



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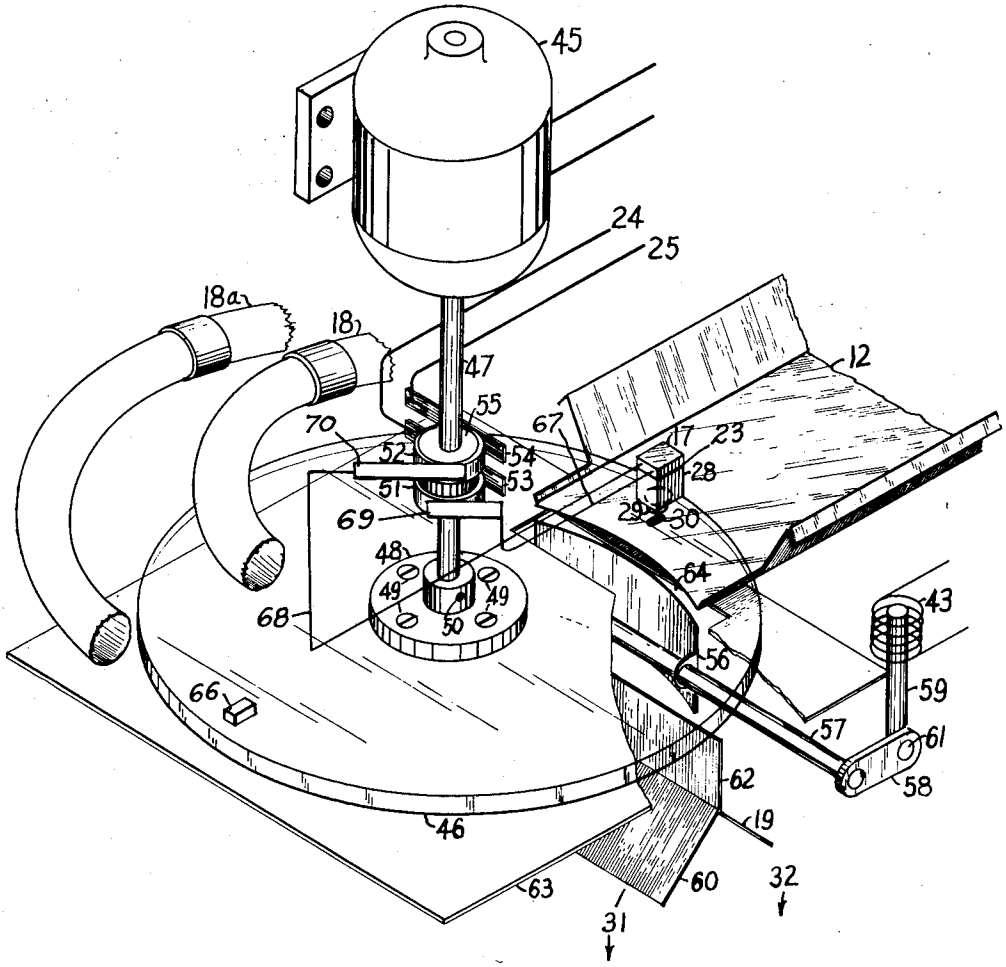


Fig. 2

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United States Patent Office 2,937,750
Patented May 24, 1960

2,937,750

COLOR SEPARATION PROCESS AND APPARATUS FOR THE REMOVAL OF IMPURITIES FROM WHOLE CORN KERNELS

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Filed Sept. 12, 1958, Ser. No. 760,818

3 Claims. (Cl. 209—111)

(Granted under Title 35, U.S. Code (1952), sec. 266)

A non-exclusive, irrevocable, royalty-free license in the invention herein described, throughout the world for all purposes of the United States Government, with the power to grant sublicenses for such purposes, is hereby granted to the Government of the United States of America.

This invention relates to the removal of impurities from whole corn kernels, and has among its objects, the provision of a process which permits the removal of rodent excreta pellets from whole corn kernels, a complete separation that is difficult or impossible to accomplish by existing methods.

One object of this invention is to provide a method for detecting the presence of rat excreta pellets in shelled corn by one or more light detecting elements which differentiate between light and dark colored objects.

Another important object is to effect the removal of rat excreta pellets by causing photoelectric cell detector to activate a removal device when objects darker in color than corn enter the field of light of said photoelectric cells.

Another important object is to remove, by optical detection, the rat excreta which is of the same size as corn but of variable density and absorbency which cannot be removed by present pneumatic, sizing, and gravity operations that are now employed in corn milling operations.

Another object of this invention is to provide a method for cleaning corn to make it more suitable for human consumption.

Another object of this invention is to augment existing cleaning methods as a final event in the cleaning process whereby evidence of completeness of removal by preceding processes is obtained.

Another object of this invention is to raise confidence in the purity of corn for human consumption beyond that obtainable by existing cleaning processes.

Another object of this invention is to combine an inspection process and a separation process in unit apparatus.

Still a further object is to provide, for the above process, an improved apparatus which is more efficient in its components and in the combination and arrangement thereof.

To these and other ends the invention resides in certain improvements and combinations of part and method, which will be hereinafter more fully described and the novel features pointed out in the claims at the end of the specification.

The methods of cleaning corn for human consumption used at present by industry consist of various combinations of screening to remove coarse and fine particles, aspiration to remove dust and light materials, and scouring to remove adhering materials. All are about 75 percent or less efficient in their removal of extraneous substances. Depending upon the kinds of screens used in the screening process, practically all of the mouse pellets and about one-half to three-fourths of the rat pellets are removed during conventional cleaning.

According to one method of procedure in the prior art, corn from the screening process is washed to remove dust, stones and materials of low density, and then dried in centrifuges or screens. About 75 percent or more of the remaining pellets, which are about the same size as corn kernels, float to the surface and are removed during the washing step.

Another method for further purifying the corn that is practiced in the prior art consists in passing the mixture from the screening procedures through a specific gravity separator operated with air. About 75 percent or more of the pellets remaining after screening are removed by this method.

According to another method of procedure in the prior art the mixture from the screening procedures is passed through precision-size separators of various types. About 75 percent or more of the pellets remaining after screening are removed by this method.

According to another method of procedure in the prior art materials of lower or higher density than corn kernels are separated by a combination of air flotation and gravity flow applied to a vibrating conveyor deck. About 75 percent or more of the pellets remaining after screening are removed by this method, some in the light fraction, and others in the heavy fraction along with stones present in the feed.

Another method for purifying corn that is practiced in the prior art consists in passing the mixture from a screening, tempering and conditioning procedure through a series of electrostatic separators. A reject fraction containing rodent excreta pellets, broken and infested kernels, insects, worms, foreign seeds, and the like, is separated from the bulk of the kernels during passage through an electrostatic field. This procedure has the disadvantage of requiring very high voltages, 20,000 to 40,000 volts, erratic performance with feed of variable moisture content, and a large number of passes to hold the reject fraction to a reasonable amount.

Another method for sorting solid particulate vegetable matter that is practiced in the prior art is by means of color. The particles are illuminated as they are individually handled and presented one at a time before one or more photocells, and if the color does not match the desired color, the particle is rejected into an off-color fraction. This apparatus has the disadvantage of limited capacity—for corn about three bushels per hour per unit, which is about 75 kernels per second. For a practical operation an excessive number of these units would be required.

Despite the use of various cleaning procedures, rat excreta pellets are often found in cleaned corn to the extent of one to four pellets per bushel of corn kernels. These pellets are usually within the size and specific gravity ranges of corn kernels.

We have discovered that color and reflectivity are properties by which rat excreta pellets consistently differ from corn kernels, and that a separation can be accomplished on this basis. The electrical response of light sensitive elements may be used to optically discriminate between the colors of corn and darker rat excreta pellets. The change in electrical response may be interpreted by a thyratron trigger circuit to initiate the action of a rat excreta pellet removal device.

We have found that cadmium sulphide photoconductive cells were suited for our applications where space was limited, response time requirements were moderate (.001 second or longer) and miniaturization of the light sensitive component was necessary to permit rapid rotational or oscillatory motion. However a system of lenses, prisms

and mirrors could also have been used to transmit light information to a stationary photomultiplier tube having instantaneous response, from the point traversing a scan line, thereby permitting faster scanning rates.

A more practical mass scanner for a moving monolayer of contaminated shelled corn would be possible by employing a closed circuit television camera as multiple light sensitive elements with provisions for operation of a rejection device when a pellet is scanned. A belt two feet wide carrying a compact monolayer of kernels moving at a speed of one foot per second could carry about 100 bushels per hour.

We have also discovered that a small coating of surface moisture such as would result from fallout from a water fog enhances contrast between light colored pellets and corn kernels and makes their separation possible.

Figure 1 is a diagram showing equipment and sequence of operation involved in carrying out a preferred embodiment of our invention, and a schematic diagram of an electronic controller that can be used to activate the rejection device at the correct time and for the proper interval of time.

Figure 2 is a perspective view showing an adaptation of the method and apparatus embodying the present invention.

While one embodiment of the invention is illustrated in the above referred to drawings, it is to be understood that it is merely for the purpose of illustration and that various changes in construction may be resorted to in the course of manufacture in order that the invention may be utilized to the best advantage according to circumstances that may arise without in any way departing from the spirit and intention of the device, which is to be limited only in accordance with the appended claims. And while there is stated the primary field of utility of the invention, it remains obvious that it may be employed in any other capacity wherein it may be found applicable.

In the practice of our invention as shown in Figure 1, the raw corn is fed from a loading elevator to milling separator **10** of known construction, which removes coarser foreign materials, such as corn cobs, pieces of wood, stones, etc., dust, lightly adhering solids, and large and small particles including some rat and all mouse excreta pellets. The mixture discharged from this milling operation is then conducted through chute **11**.

After this preliminary cleaning operation, the mixture may then be passed directly to devices for efficient rat pellet removal by means comprising optical detector activated separation apparatus as hereinafter described.

The mixture is fed to hopper **11** over the vibratory feeder and is spread out in a layer one kernel deep on the metal vibratory feeder **12**. Under the influence of the oscillatory motion of the pan of the vibratory feeder the compact monolayer of mixture is caused to move at a uniform linear rate so that for an instant each particle of the mixture resides entirely within the boundary of the arcuate scanning zone of Figure 2, and is thus subjected to discrimination between light and dark by means of light-sensitive element **23**.

Said light sensitive element **23**, in the preferred embodiment of our invention, is shown in Figure 1 as a cadmium sulfide photoconductive cell and is connected through conductors **24** and **25** to electronic controller (indicated generally as **39**) which impresses a low direct current voltage upon said element. The distance between light sensitive element **23** and the light reflective object **30** is established by the diameter of the object, the perimeter of the light sensitive element and the characteristic of the lens **29**. In our invention we used a cadmium sulphide photoconductive cell operating as a non-polar variable resistor that passed more current as illumination increased. The element had an initial dark resistance in excess of one megohm and a peak spectral response at 5100 angstroms. With reference to Figure 1, optimum performance with the cadmium sulphide photoconductive cell was obtained by using a 20× microscopic objective lens **29** to focus on images of corn or excreta **30** with successive full images of each and every particle touching but centered within the 5/16 inch by 7/16 inch periphery of the photosensitive area **23** at some instant during their passage through the scanning zone. Our particular arrangement required an object distance of 21 1/32 inch from the lens and a total distance of 1 27/32 inches between object **30** and photosensitive surface **23**. A deviation from these conditions resulted in failure of the particular photocell employed to discriminate between corn and equal sized rat excreta pellets. If the image of object **30** cast upon photosensitive surface **23** had an area substantially less than the area of **23**, the electrical response of the element **23** was not sufficient in magnitude to be distinguished from normal background noise (repetitious irregularities in response). Since deep shadows necessarily occur at the interstices between contacting kernels of the monolayer passing through the arcuate scanning zone of Figure 2 greater magnification of object **30** would also magnify the shadow image proportionately. With a shadow image substantially covering area **23**, the result was failure of the cell to distinguish between shadows and rat excreta pellets. The "sight" of the photosensitive device therefore becomes a critical aspect of our invention as will hereafter be described in the claims.

Referring now to Figure 2, the mass scanner of this invention includes a conventional vibratory feeder **12** fed from hopper **11**, not shown, a variable speed motor **45** of known construction rotatably connected to transparent scanner disc **46**, by means of drive shaft **47**, opposite ends of which are attached to motor **45** extending into and secured in the hub of flange coupling **48** by means of set screw **50**. Flange **48** is concentrically attached to disc **46** by means of four flat head flange bolts **49**, means by which disc **46** is caused to rotate.

In a perforation within the periphery of disc **46** a light sensitive element assembly comprising a 20× microscope objective **29**, a tubular body **28**, and a photoconductive surface **23** encapsuled in plastic body **17** as shown in Figure 2 is inserted and secured within said perforation through disc **46**. Plastic counterweight **66** is attached in diametrical opposition to this photocell assembly on disc **46**.

In Figures 1 and 2 electrical continuity between light-sensitive element **23** and electronic controller **39** is obtained through conductors **67** and **68** which are connected to brushes **69** and **70**, respectively. These brushes are in turn connected to brushes **53** and **54** and lines **24** and **25** through slip rings **51** and **52**, respectively.

Metal slip-rings **51** and **52** are shrunk on each end of cylindrical insulating body **55**. Shaft **47** extends through and is affixed in the bore of insulating body **55** concentric with the cylindrical periphery of slip-rings **51** and **52**, means by which the slip-rings are caused to rotate with the disc **46** and shaft **47**.

In Figure 2 brushes **53** and **54** are positioned to maintain contact with slip-rings **51** and **52** respectively by attachment to an electrical insulating structure (not shown) of known material and construction.

Scanning disc **46** is positioned in a plane parallel to and above the plane of vibratory feeder **12** and supported by bolts holding the base of motor **45** to a rigid supporting structure of known construction. Concentric with and above the circular orbit of photosensitive element **28** are located two circular fluorescent light tubes **18** and **18*a***, **18** being of smaller radius and **18*a*** of greater radius than the circular orbit of element **28**.

Positioned in a plane parallel to and below the plane of vibratory feeder pan **12**, a reflective screen **63** is attached to a supporting structure by conventional means, said screen having sufficient area to contain the circular orbit of photosensitive element **28**. The light reflective properties of screen **63** are such that the electrical re-

sponse of light sensitive element 23 is equal to or exceeds the brightness response of corn under conditions of illumination provided by lamps 18 and 18a, and response remains steady during the retrace orbit.

A rectangular opening 64 in reflecting screen 63 is located within the circular path of scan and directly below the edge of vibratory feeder pan 12 through which the mixture drops to the separation zone. All surfaces of vibratory feeder pan 12 visible to photoelectric element 23 in its arcuate travel over the lip of said pan are coated with a colored material having light reflecting properties equal to or greater in brightness than the compact monolayer of corn moving across the surface of said pan.

With pan 12 and reflecting screen 63 arranged according to the preceding specifications and illustration in Figure 2, the surface visible to light sensitive element 23 in its circular travel is all equal to or of a higher level of reflectivity than a compact monolayer of corn.

Shaft 57 positioned below and transverse to feeder pan 12, having both ends journaled in a ridged supporting structure, pivotably supports sheet metal deflecting gate 56 by means of integral lugs located at each end of arcuate deflecting gate 56 which are bent to form right angles with a chord across the arc of the curved surface to which the sheet metal gate is formed. Shaft 57 passing through perforation in both lugs is preferentially attached by welding. The radius of the arc to which the gate 56 is formed, and of the discharge lip of feeder pan 12, corresponds to radius of the circular orbit traveled by photosensitive element 28, thereby obtaining a constant time for a particle of the monolayers movement from the arcuate scanning zone to the separation zone located between the curved edge of the feeder pan 12 and the upper edge of deflecting gate 56 in the reflecting screen opening 64.

Deflecting gate lever 58 is affixed to one end of shaft 57, a pin 61 pivotally connects the free end of lever 58 to the lower end of armature rod 59, thereby enabling solenoid 43 when energized to tilt deflecting gate 56 and divert reject material to the rear side of divider plate 62 down reject chute 19 to reject bin 32.

With the parts assembled as illustrated and described, the corn cleaning apparatus is mounted on a frame or structure and augments conventional cleaning equipment. In Figure 1, the power supply provides the necessary voltages used in the control circuit 39. When a dark object enters the scanning zone of Figures 1 and 2, the voltage applied to the grid of Thyratron tube 40 causes it to fire and close the single pole double throw relay 33. The sensitivity of the controller is determined by the sensitivity adjustment 36. Closing of the single pole relay 33 allows the tube 37 to pass increased plate current to the double-pole double-throw relay 34, but only after a time delay introduced by condenser 35 and time delay adjustment 42. Closing of the double-pole double-throw relay 34 allows power to flow to the deflecting gate solenoid 43 which tilts deflecting gate 56 so that the dark object and some corn pass to reject bin 32. The length of time during which the deflecting gate remains in the reject position is determined by the adjustment of the hold control 44 of the controller. The plate current to the double-pole relay 34 decreases and allows it to open after the proper hold time. The plate current of the Thyratron 40 was broken when double-pole relay 34 closed so that the controller has now reset and is ready to detect and reject another dark object. Good corn falls in front of deflecting gate 56 and chute divider plate 62, down chute 60 to clean corn bin 31.

In Figure 1 a television camera (not shown) may be substituted for the scanning disc assembly as a color discriminating device for a traveling compact monolayer of corn having a low population of equal sized dark objects. Said camera is positioned over feeder pan 12 and focused so that the image of a tranverse line or area of the illumined monolayer of corn would exactly span the

light sensitive surface of the television camera. By elimination of the blanking pulse from the television camera electronic apparatus a signal is obtained when a dark object 30 enters the sight of the television camera which is used to provide the voltage to the grid of Thyratron tube 40 of the control circuit 39. The resulting chain of events leading to the elimination of the dark object from the good corn is the same as heretofore described for the scanning disc assembly. Deflecting gate 56 tilts and the dark object 30 and a small amount of good corn pass to reject bin 32.

The loss of good corn is further reduced by recycling the first reject fraction through a second color discrimination cleaning process and combining the clean corn from it with the clean corn from the first process.

We claim:

1. In an apparatus of the character described means for continuously delivering at a uniform rate a monolayer of a mixture of light and dark objects to an arcuate inspection zone; a transparent disk rotatably mounted above said inspection zone so as to rotate in a plane parallel to the plane of movement of said mixture of light and dark objects; a plurality of circular illuminating means of different diameters concentrically mounted above said transparent disk and parallel to the plane thereof; photosensitive means mounted on said transparent disk with the photosensitive surface disposed in the direction of the moving light and dark objects and located at such a distance from the center of rotation of the disk and from the centers of the circular illuminating means as to be on a radius intermediate in length between the longest and shortest radius of the circular illuminating means; and a lens system disposed between the photosensitive means and the plane of moving light and dark objects adapted to project an image of a single object large enough to fall entirely within the photosensitive area and to touch the perimeter thereof.

2. In an apparatus of the character described means for continuously delivering at a uniform rate a monolayer of a mixture of light and dark objects to a reflective surface in an arcuate inspection zone; a transparent disk rotatably mounted above the reflective surface so as to rotate in a plane parallel to said reflective surface and to the plane of movement of said mixture of light and dark objects, said reflective surface being adapted to reflect light of intensity at least equal to that of the light objects; a pair of concentric circular illuminating means of different diameters mounted above said transparent disk concentric therewith and parallel to the plane thereof; photosensitive means mounted on said transparent disk with the photosensitive surface disposed in the direction of the moving light and dark objects and located at such a distance from the center of rotation of the disk as to be between said pair of circular illuminating means; and a lens system disposed between the photosensitive means and the plane of moving light and dark objects adapted to project an image of a single object large enough to fall entirely within the photosensitive area and to touch the perimeter thereof.

3. Color sorting apparatus for separating dark and light objects comprising means for continuously delivering at a uniform rate a monolayer of a mixture of light and dark objects to a reflective surface in an arcuate reflecting zone; a transparent disk rotatably mounted above the reflective surface so as to rotate in a plane parallel to said reflective surface and to the plane of movement of said mixture of light and dark objects, said reflective surface being adapted to reflect light of intensity at least equal to that of the light objects; a pair of concentric circular illuminating means of different diameter mounted above said transparent disk concentric therewith and parallel to the plane thereof; photosensitive means mounted on said transparent disk with the photosensitive surface disposed in the direction of the moving light and dark objects and located at such distance from the center of rotation of the disk as to be between said pair of circu-

lar illuminating means; a lens system disposed between the photosensitive means and the plane of moving light and dark objects adapted to project an image of a single object large enough to fall entirely within the photosensitive area and to touch the perimeter thereof; a Thyratron trigger circuit connected to said photosensitive means; discharge means capable of discharging objects in two different directions, said discharge means being connected to and being operable by said Thyratron trigger circuit to discharge dark objects in one direction upon receipt of a dark signal from the photosensitive means and to discharge light objects in another direction upon receipt of a light signal from the photosensitive means, said Thyratron trigger circuit containing time delay elements whereby said discharge means are not activated until an object has had time to pass from the inspection zone to the discharge boundary and whereby said discharge means are maintained open long enough for the object to be ejected from the apparatus.

References Cited in the file of this patent

UNITED STATES PATENTS

2,125,639	Maass et al.	Aug. 2, 1938
2,701,502	Lukens et al.	Feb. 8, 1955
2,726,762	Aubry	Dec. 13, 1955
2,798,605	Richards	July 9, 1957
2,803,161	Summerhayes	Aug. 20, 1957
2,881,919	Bartlett	Apr. 14, 1959