

June 16, 1964

D. L. SLIGHT

3,137,392

APPARATUS FOR SEPARATING CROPS FROM OTHER MATTER

Filed May 15, 1961

6 Sheets-Sheet 1

FIG. 1

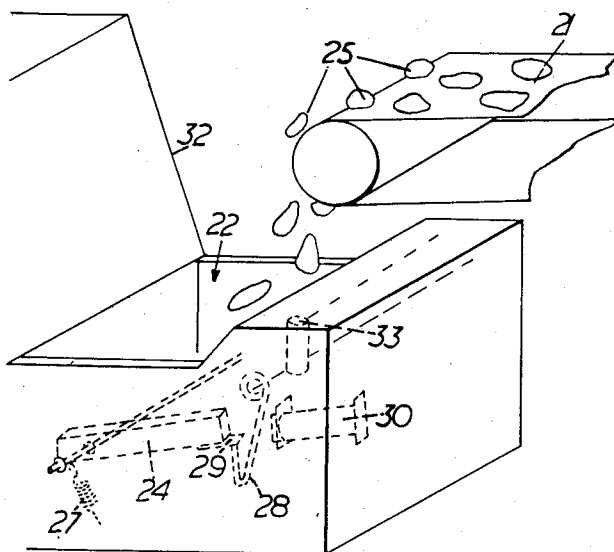
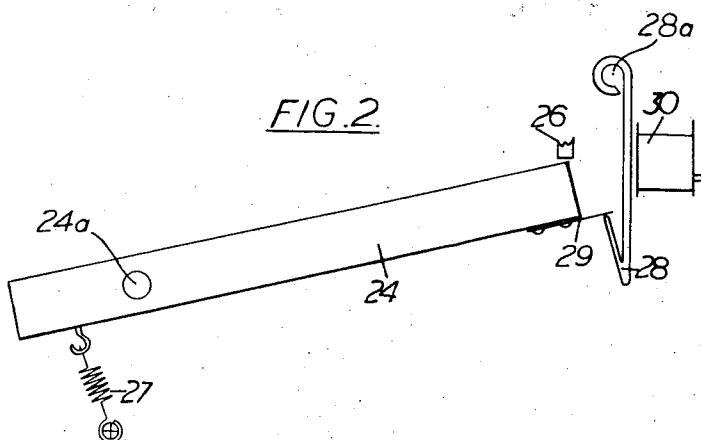


FIG. 2



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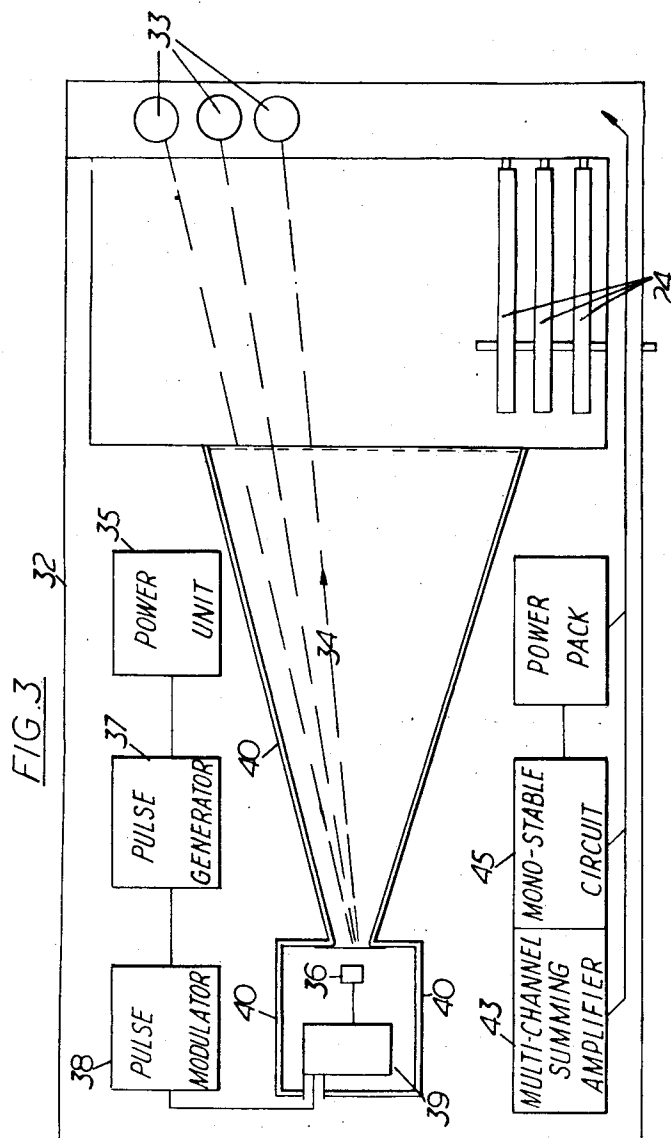
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6 Sheets-Sheet 2



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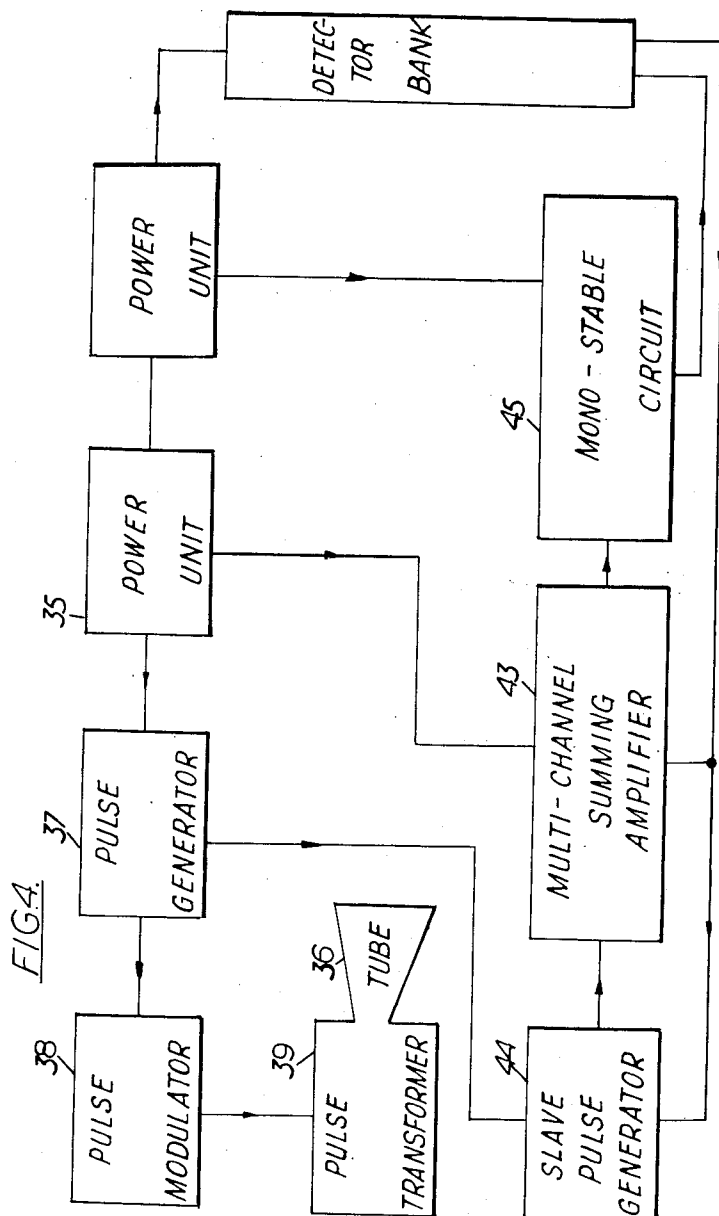
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APPARATUS FOR SEPARATING CROPS FROM OTHER MATTER

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6 Sheets-Sheet 3



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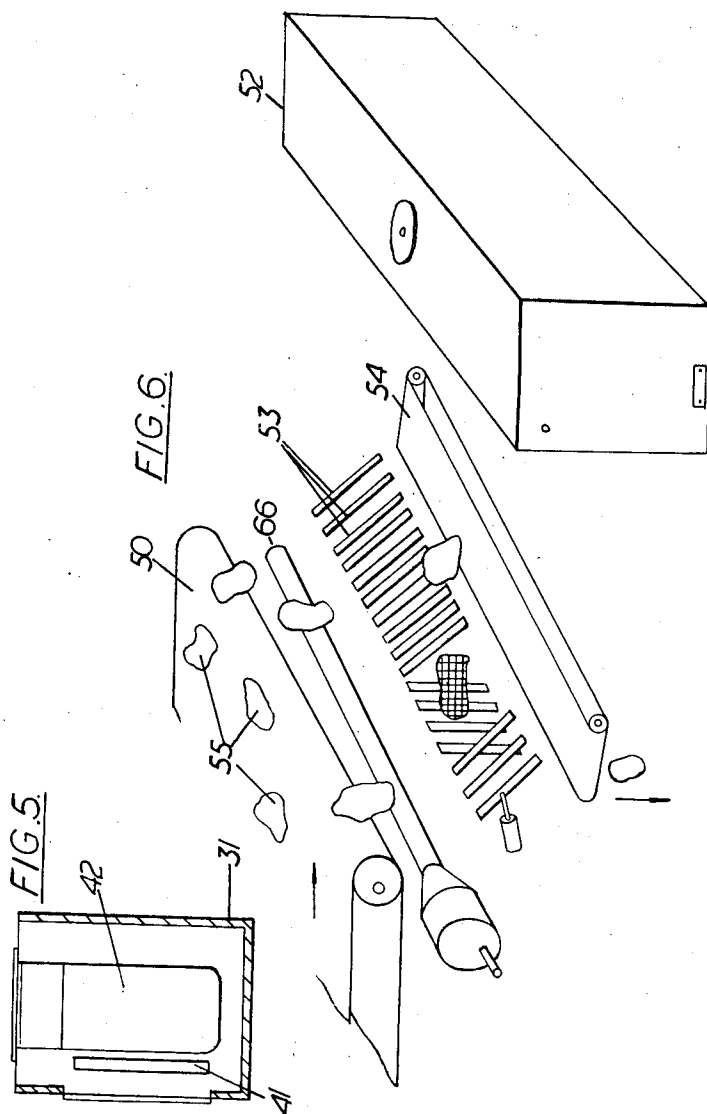
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APPARATUS FOR SEPARATING CROPS FROM OTHER MATTER

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6 Sheets-Sheet 4



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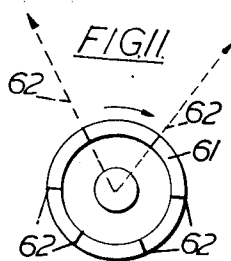
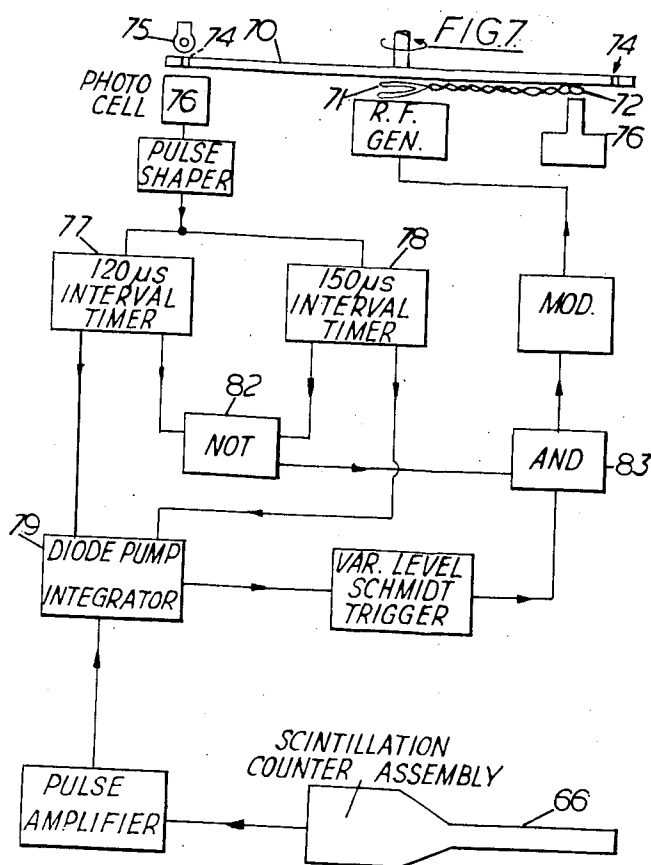
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APPARATUS FOR SEPARATING CROPS FROM OTHER MATTER

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6 Sheets-Sheet 5



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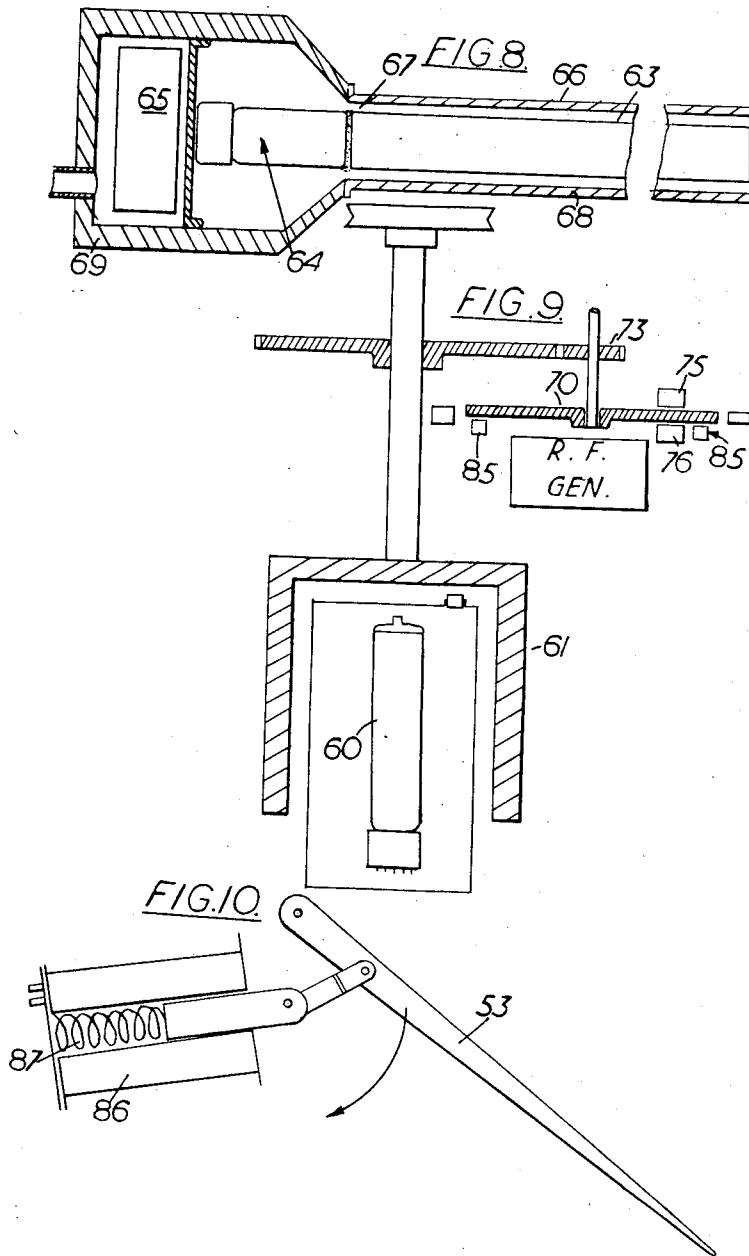
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APPARATUS FOR SEPARATING CROPS FROM OTHER MATTER

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6 Sheets-Sheet 6



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3,137,392

APPARATUS FOR SEPARATING CROPS FROM OTHER MATTER

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15 Claims. (Cl. 209—111.5)

This invention relates to apparatus of the type for separating crops from other matter and is particularly but not exclusively applicable to apparatus for the separation of root crops from stones, earth and the like and including such equipment.

According to the present invention there is provided apparatus of the type specified including a source of ionizing radiation, radiation detection means, means for feeding the crop and the other matter through the beam of radiation reaching the detection means, and separating means adapted to be operated by said detection means in accordance with radiation received thereby to separate said crops from said other matter.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings, in which:

FIG. 1 is a general view of a first embodiment;

FIG. 2 is a view of a separator key used in the first embodiment;

FIG. 3 is a plan view of the apparatus showing the layout of the various components;

FIG. 4 is a circuit diagram of the first embodiment;

FIG. 5 is a view of an intensity detector used in the first embodiment;

FIG. 6 is a general view of a second embodiment;

FIG. 7 is the circuit diagram of the second embodiment;

FIG. 8 is a view of the intensity detector used in the second embodiment;

FIG. 9 is a view of the rotating cylinder and distributor disc of the second embodiment;

FIG. 10 is a detail view of a separator key of the second embodiment; and

FIG. 11 is a plan view of the X-ray tube and rotating cylinder of the second embodiment.

Referring now to FIG. 1, a generally horizontally disposed belt conveyor 21 delivers harvested potatoes and stones 25 to a vertically inclined chute 22. This chute terminates at its lower end with a two-way separator formed from a series of releasable keys 24 extending across its width and defining the bottom of the chute 22. These keys 24 are inclined at about 30° to the horizontal and present a sloping surface leading towards a delivery chute (not shown).

As shown in FIG. 2, the releasable keys 24 are pivotally mounted at 24a adjacent their lower ends, their upper ends being spring-urged upwards against a stop 26 which limits the inclination of the key. Each spring 27 has a strength which just more than counterbalances the weight of the key, so that any object striking a key 24 will cause it to pivot and the object will drop through the space beneath.

A series of latches 28, pivotally mounted at 28a at the upper end thereof, are provided adjacent the upper ends of the keys 24 and each is arranged to hang in its normal position so as to present an abutment to a plate 29 mounted on the underside of the upper end of the adjacent key. A series of solenoids 30 are also provided one for each latch 28, each of which acts when energized to draw one of the latches 28 towards it and away from the key 24 so that the latter may pivot to allow an object to pass through. If however any solenoid 30 is de-energized its associated latch 28 will be beneath the

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plate 29 mounted on the underside of the key 24 and will prevent the latter from pivoting downwards. As a result as long as the solenoid 30 is de-energized the key will not move and any object striking it will fall downwards in the sense of its inclination to the delivery chute. In this embodiment the potatoes are intended to pass to the delivery chute and the stones to pass through the keys 24 to be discharged.

It is arranged that the solenoids 30 are selectively energized by detection means. The detection means are energized by a source of ionizing radiation located in a housing 32 on one side of the chute 22 and comprise a bank of intensity detectors 33, one corresponding to each key, located on the other side of the chute 22. Potatoes and stones passing down the chute 22 and through the radiation beam 34 cause the intensity of radiation received by each intensity detector 33 to vary.

In theory the intensity detectors 33 emit signals which represent three types of information, namely

- (1) The width of the object intercepting the radiation.
- (2) The position of this object, and
- (3) The character of the object.

This data is subsequently processed in a computer and used to effect the separating operation. In practice this data is in the form of a variation in the intensity of the radiation reaching the bank of intensity detectors 33. This variation in intensity is used by each intensity detector 33 either to energise or de-energise its associated solenoid 30 and latch 28; thus if a stone interrupts the beam to one intensity detector, the intensity signal is passed to the computer which after a predetermined time interval energises the corresponding solenoid. As a result, when the stone reaches the key 24 it opens freely. On the other hand, when a potato passes through the beam 34 the intensity detector is somewhat greater and as a result the computer causes the solenoid to be de-energised and thus the key is held in the position to deflect the potato towards the discharge chute.

Referring now to FIG. 3 which schematically shows the embodiment, the beam of ionising radiation 34 is obtained from a small X-ray tube 36, although any other suitable source could be utilised. In order to reduce radiation hazard to very small proportions the emitted radiation is pulse modulated and the source is almost completely shielded. Using electrical energy derived from either the mains or from batteries (diagrammatically shown as power unit 35 in FIG. 4), a cathode coupled multivibrator 37 is used as a pulse generator to generate pulses of about one microsecond's duration at a rate of about twenty-five a second. These pulses are amplified by a pulse modulator 38 and are then passed to a pulse transformer 39 which feeds the X-ray tube 36. A lead shield 40 houses the X-ray tube 36 and permits radiation therefrom to pass through a horizontal slit (not shown) in the side of the detection chute 22 to impinge on the horizontally disposed bank of intensity detectors 33.

As shown in FIG. 5, each intensity detector 33 uses a luminophor 41, for example lead sulphide, in association with a photosensitive device, for example a photo electron multiplier 42. The luminophor 41 produces flashes of light proportional to the intensity of the radiation striking it and these are converted into electrical impulses by the photo electron multiplier 42. The detector 33 is provided with a lead housing 31, the ray 34 passing through an aluminium window 23.

The computer comprises a multi-channel amplifier 43 and a monostable circuit 45. The output from each multiplier 42 is fed to the multi-channel summing amplifier 43 along with a second pulsed input from a slave pulse generator 44, the pulses of which occur at the same time as the multiplier pulses. The two series of pulses are

normally arranged to be equal in magnitude but of opposite polarity, and normally cancel each other out. When a potato passes through the radiation beam 34 this condition is not upset. However when a stone passes through the radiation beam to one intensity detector 33, the multiplier pulse is reduced substantially to zero and as a result the two pulses no longer cancel each other out; the resultant output pulse is used to trigger the mono-stable circuit 45, which in turn energises the particular solenoid 30 and keeps it energised for a sufficient time to allow the stone to strike the key 24, or keys, if the stone is large enough to interrupt the beam 34 to several of the intensity detectors 33.

Thus in effect, when a stone passes down the chute 22, the beam 34 to one or more intensity detectors 33 is interrupted, the corresponding solenoids 30 are operated and when the stone strikes the keys 24 it passes through to be discharged. When a potato passes down the chute 22 the beams are not interrupted sufficiently to operate the solenoids and the potato strikes the keys and rolls down the incline into the delivery chute.

The separator may be a stationary apparatus, or alternatively it may form part of a harvester and be adapted to move along with it.

Some typical values of some of the variables involved are given purely by way of example.

X-ray tube—S.T.C. type 4072.

Radiation pulse duration—1 microsecond.

Radiation pulse frequency—25 per second.

X-ray tube voltage—40 kv. peak.

The operation of a second embodiment of the invention is similar to that of the first and is illustrated in FIG. 6 which shows a belt conveyor 50 feeding potatoes and stones 55 to a vertical chute (not defined). As the potatoes and stones pass down the chute they interrupt a beam of ionising radiation between a source in a housing 52 and a detection means assembly 66. A series of releasable keys 53 forms a two way barrier extending across the chute to deflect the potatoes onto the belt conveyor 54 and to allow the stones to pass through the barrier in accordance with signals from the assembly 66.

The ionising radiation is obtained from a small X-ray tube 60 (see FIG. 11) mounted inside a vertical cylinder 61 which carries a number of narrow, vertical, equispaced slots 62, e.g. six at 60° intervals. The cylinder 61 but not the tube 60 rotates at 2,000 r.p.m. in the present embodiment and the slots 62 thus serve as collimators and cause beams of radiation to scan the horizontally disposed detection means assembly 66.

As shown in FIG. 8, the detection means of the embodiment consists of a 30" length of transparent, synthetic resin scintillator 63 in the form of a one inch diameter cylinder associated with a one inch photo electron multiplier tube 64. The scintillator 63 is of the type designated NE 102 and has a highly polished surface, all but one end being coated with a compacted powder reflector. The uncoated end is bonded to the photo-electron multiplier tube with a thin film 67 of silicone grease. The scintillator 63 is mounted inside an aluminium tube 68 closed at one end while the other end makes a light tight joint with the photo-multiplier housing 69 which consists of half inch thick mild steel. Also mounted within the photo-multiplier housing are a pre-amplifier 65 together with the power supply stabilizer (not shown) for the photo-multiplier tube 64.

The detection means assembly 66 is mounted at such distance from the cylinder 61 that it subtends an angle of 60° at the radiation source i.e. the scan of one beam is completed before the following scan starts.

As shown in FIG. 9 associated with the cylinder 61 and driven by gearing 73 from it, is a distributor disc 70 which carries a radio frequency inductive link, one of the link coupling coils 71, FIG. 7, being mounted co-axially with the disc and the other 72 mounted on a parallel axis near the periphery. The disc 70 also carries 30 small

holes 74 forming a circle near the periphery and on radii with 12° spacing. The disc 70 rotates at six times the speed of the cylinder 61 and the circle of holes 74 serves to interrupt the path of light between a lamp 75 and a photo-cell 76. The photocell output therefore consists of a series of electrical impulses each corresponding to the passing of a hole. These pulses are used to trigger two interval timers 77 and 78, one, 77, operating for a 120 μ s. period and the other, 78, for a 150 μ s. period. Both periods start at the same instant. The 120 μ s. period is used to switch the output from the assembly 66 to a diode pump integrator 79 which builds up a D.C. level at its output which is directly proportional to the count. The 150 μ s. period is used to operate a device which allows the D.C. at the diode pump output to build up and at the end of the 150 μ s. period the D.C. level is reset to zero.

The result of these two actions is that for 120 μ s. after the trigger, the D.C. level is building up to a value which depends on the count and for the next 30 μ s. this D.C. value is maintained at a steady voltage, no further count is run up during this 30 μ s. period. At the end of this period the D.C. is removed and the diode pump 79 is ready to restart the cycle.

During the period of one scan, the distributor disc 70 makes one revolution and 30 trigger pulses are obtained from the photo-cell 76. The diode pump integrator 79 therefore completes 30 separate counting periods each approximating to a movement of one inch of the beam of radiation along the scintillator 63. The computer 80, comprising the two interval timers 77 and 78, the diode pump integrator 79 and two gates, thus makes 30 decisions during the time taken for one complete scan and if any one or more of these is such that the keys 53 are required to operate, the distributor disc 70 ensures that the particular key is operated which is situated immediately below the beam position at the time of the decision. The object which caused the decision is therefore rejected.

The decision to reject an object arises when the D.C. voltage at the output of the integrator fails to reach a critical, preset value during the 120 μ s. counting period.

The outputs of the two interval timers, 77 and 78, are also fed to a NOT gate 82 which produces a 30 μ s. pulse corresponding to the difference. These two 30 μ s. pulses, the first originating when the D.C. level of the diode pump 79 fails to reach a critical preset value and the second which is always produced by the NOT gate 82, are fed to an AND gate 83 which only gives an output if the two pulses exist and only when they are coincident. The result is a 30 μ s. pulse when the count fails to reach the critical value showing that a radio opaque object is passing through the radiation beam. The critical value is adjustable and thus it is possible to accept or reject objects whose radio opacity differs only slightly. In the usual operation of the equipment potatoes will be accepted and stones and clods will be rejected.

The 30 μ s. pulse which appears at the output of the AND gate 83 is required to operate the appropriate key 53 and this is accomplished by using the pulse to switch on a radio frequency generator 84. The frequency is of the order of 27 mc./s. and the power approximately 5 watts. The output from the RF generator 84 is fed to the coaxial coupling coil 71 of the radio frequency inductive link on the distributor disc 70 and the power appears at the peripheral coupling coil 72. From this coil it is transferred, inductively, to whichever resonant detector circuit 85 the coil 72 is opposite at that instant. There are 30 resonant detector circuits 85 spaced at 12° intervals and each connected to a key 53. The current is then rectified and the resulting pulse used to trigger the associated key. A simple advance/retard system (not shown) ensures correct timing.

In this embodiment the 30 separator keys 53 correspond to the 30 counting periods during one scan and each of these is arranged so that it may be triggered by

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a 30 μ s. pulse picked up by its associated resonant circuit from the distributor RF link.

As shown in FIG. 10, each electro-mechanical separator key 53 is hinged near the upper end thereof. Each finger 53 is inclined at an angle of 30° to the horizontal and normally deflects potatoes. However, on being actuated, the key 53 falls to a vertical position and allows the object to fall through. The key is held in the normal position by spring loading and it is actuated by a solenoid 86. Each spring 87 is strong enough to return the key 53 to the normal position when the solenoid 86 is de-energised. The circuit between the resonant detector circuit 85 and the solenoid 86 consists of a delay device to lengthen the 30 μ s. pulse to about 100 μ s. followed by an amplifier to operate the solenoid.

The power source for the whole equipment is 12 v. D.C. from a vehicle battery and charging system. High voltage for the X-ray tube is obtained by transforming chopped D.C. at 12 volts produced by a transistorised power oscillator up to about 15 kv. and feeding this output to a voltage quadrupler circuit which provides D.C. at its output at the correct voltage for the tube. The four rectifiers are thermionic types with heaters supplied from separate windings on a second transformer, the secondary being highly insulated and the transformer being mounted in an oil bath together with all other high voltage components.

A power supply of about 300 volts is required for the scintillation amplifier and RF generator and this is obtained from a transistorised converter operating from the 12 volt supply. A voltage multiplier incorporated in this unit is used to obtain EHT of about 2,000 volts which is rectified and stabilised to provide power for the photo-electron multiplier tube.

The apparatus may be used for the separation of various crops from other matter, for example root crops, such as turnips, and carrots. It may also be used with, for example bulbs or tomatoes.

As a result of the invention a very high rate of separation may be achieved and this rate is limited only by the rate at which the actual separating means can operate.

I claim:

1. Apparatus for sorting bodies into at least two categories in dependence upon the degree of transmission of ionising radiation and comprising a source of ionising radiation for producing a beam of radiation comprising a series of pulses of short duration, means for passing said bodies through the beam, the effective zone of said beam having an appreciable dimension transverse to the general direction of movement of the bodies through the beam, detection means responsive to the radiation received and diverting means controlled by said detection means to divert at least one said category from a succession of said bodies, said diverting means comprising a plurality of independently operating mechanisms arranged at different positions transversely with respect to said general direction, whereby bodies passing at random through any part of the beam of radiation are sensed for functioning of the appropriate diverting mechanism.

2. Apparatus as claimed in claim 1, in which separate detecting means are provided in association with each said diverting mechanism.

3. Apparatus for sorting bodies into at least two categories in dependence upon the degree of transmission of ionising radiation and comprising a source of ionising radiation, means for causing the ionisation radiation in effect to sweep as a narrow beam substantially transverse to the general direction of movement of the bodies through the beam, means for feeding said bodies through the beam, detection means responsive to the radiation received and comprising a scintillator arranged to be swept by the narrow radiation beam, and diverting means controlled by said detection means to divert at least one

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said category from a succession of said bodies, said diverting means comprising a plurality of independently operating mechanisms arranged at different positions transversely with respect to said general direction, whereby bodies passing at random through any part of the beam of radiation are sensed for functioning of the appropriate diverting mechanism.

4. Apparatus as claimed in claim 3, in which a rotatable collimator surrounds the source to provide the sweeping beam and in which means synchronising with the rotatable collimator is provided to ensure operational readiness of the appropriate diverting mechanism.

5. Apparatus as claimed in claim 4, in which the synchronising means comprises a distributor disc driven by the collimator, said disc having radio frequency links to enable the output of the scintillator to be associated with the appropriate diverting mechanism in turn.

6. Apparatus as claimed in claim 2, in which the source is an X-ray tube.

7. Apparatus for sorting bodies into at least two categories in dependence upon the degree of transmission of ionising radiation and comprising a source of ionising radiation for producing a beam of radiation, means for feeding said bodies in random array through the beam, the effective zone of said beam having an appreciable dimension transverse to the general direction of movement of the bodies the said feed means being adapted so that each body is arranged to pass at random across a part of the beam, detection means responsive to the radiation received and diverting means controlled by said detection means to divert at least one said category from a succession of said bodies, said diverting means comprising a plurality of independently operating mechanisms arranged at different positions transversely with respect to said general direction, whereby bodies passing at random through any part of the beam of radiation are sensed for functioning of the appropriate diverting mechanism.

8. Apparatus as claimed in claim 7 in which separate detecting means are provided in association with each said diverting mechanism.

9. Apparatus as claimed in claim 8, in which the ionising radiation is beamed as a series of pulses of short duration.

10. Apparatus as claimed in claim 7, in which means are provided for causing the ionising radiation in effect to sweep as a narrow beam substantially parallel to the direction of said beam dimension and in which said detection means comprises a scintillator arranged to be swept by the narrow radiation beam.

11. Apparatus as claimed in claim 10, in which a rotatable collimator surrounds the source to provide the sweeping beam and in which means synchronising with the rotatable collimator is provided to ensure operational readiness of the appropriate diverting mechanism.

12. Apparatus for sorting bodies into at least two categories in dependence upon the degree of transmission of ionising radiation and comprising a source of ionising radiation for producing a beam of radiation, means for feeding said bodies in random array and with a continuity of movement through the beam, the effective zone of said beam having an appreciable dimension transverse to the general direction of movement of the bodies through the beam, detection means responsive to the radiation received and diverting means controlled by said detection means to divert at least one said category from a succession of said bodies, said diverting means comprising a plurality of independently operating mechanisms arranged at different positions transversely with respect to said general direction, whereby bodies passing at random through any part of the beam of radiation are sensed for functioning of the appropriate diverting mechanism.

13. Apparatus for sorting bodies into at least two categories in dependence upon the degree of transmission of ionising radiation and comprising a source of ionising radiation for producing a beam of radiation, means for

feeding said bodies in random array and with a continuity of movement through the beam, the effective zone of said beam having an appreciable dimension transverse to the general direction of movement of the bodies, the said feed means being adapted so that each body is arranged to pass at random across a part of the beam, detection means responsive to the radiation received and diverting means controlled by said detection means to divert at least one said category from a succession of said bodies, said diverting means comprising a plurality of independently operating mechanisms arranged at different positions transversely with respect to said general direction, whereby bodies passing at random through any part of the beam of radiation are sensed for functioning of the appropriate diverting mechanism.

14. Apparatus as claimed in claim 13, in which the ionising radiation is beamed as a series of pulses of short duration.

15. Apparatus as claimed in claim 12 in which means are provided for causing the ionising radiation in effect to sweep as a narrow beam substantially parallel to the direction of said beam dimension and in which said detection means comprises a scintillator arranged to be swept by the narrow radiation beam.

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