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(54) Abstract Title
X-ray foreign matter detecting apparatus

(57) An X-ray foreign matter detecting apparatus is provided, which is effective to suppress leakage of X-rays from the apparatus to the outside of the apparatus resulting from erroneous operation of an X-ray source when at least a portion of the apparatus is open to the outside and the X-rays are not shielded. An article is inspected by means of X-rays emitted from an X-ray source 3 and detected by a detector 20, while being transported on a transport conveyor 2. The apparatus includes at least one vacant detector 4 for detecting the non-shielding condition of the apparatus, for instance if the conveyor is removed allowing X-rays to escape though the lower portion of the curtain 18, and means to halt emission of the X-rays. A shutter may be provided to close the openings though which the conveyor extends in response to removal of the conveyor from the conveyor housing.

Fig. 2

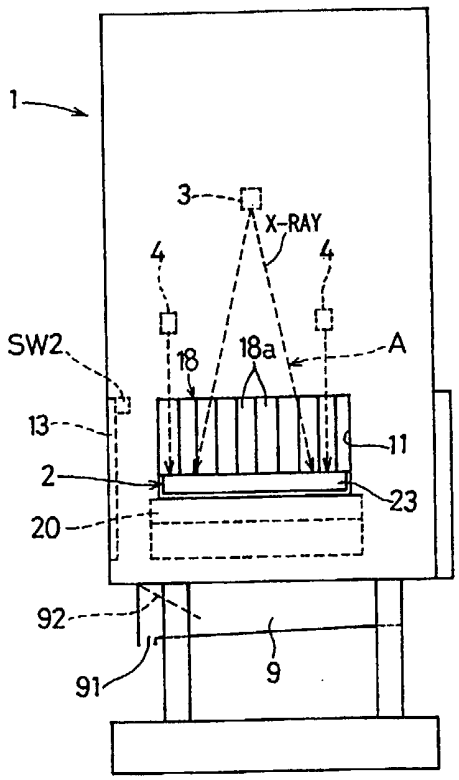

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Fig.1

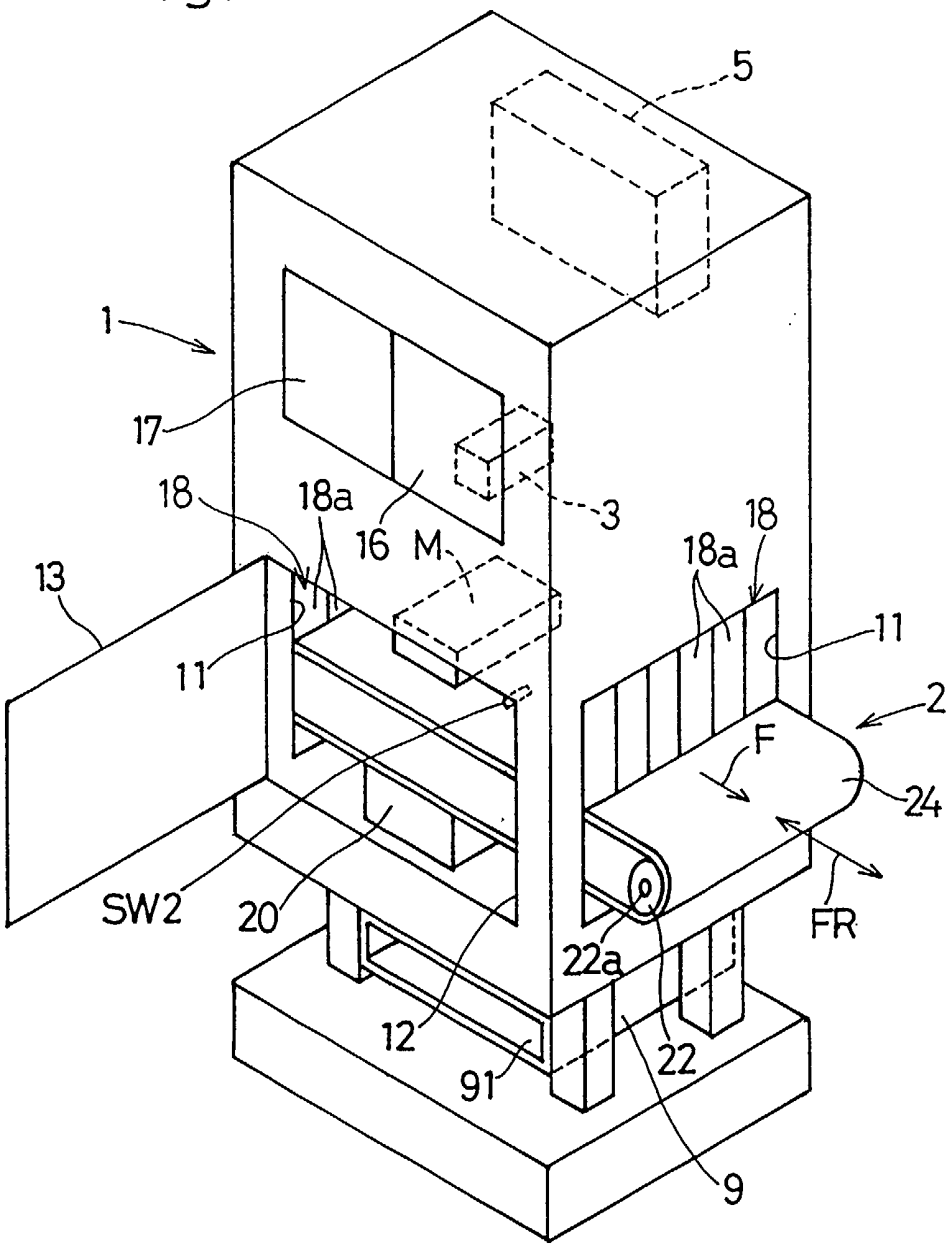


Fig. 2

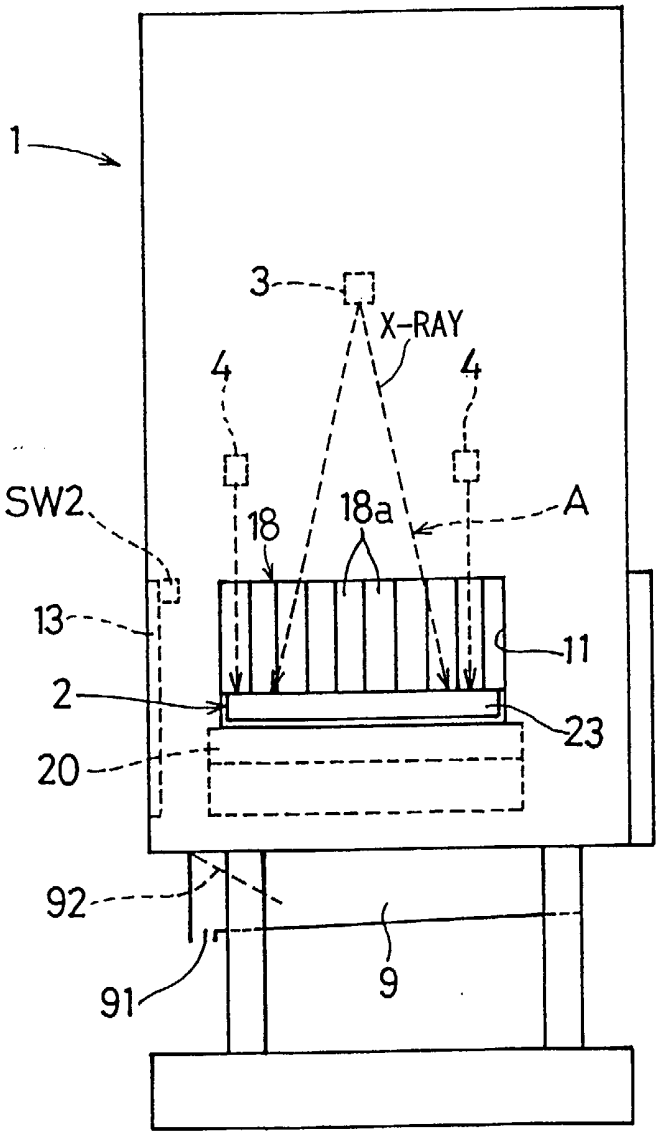


Fig. 3

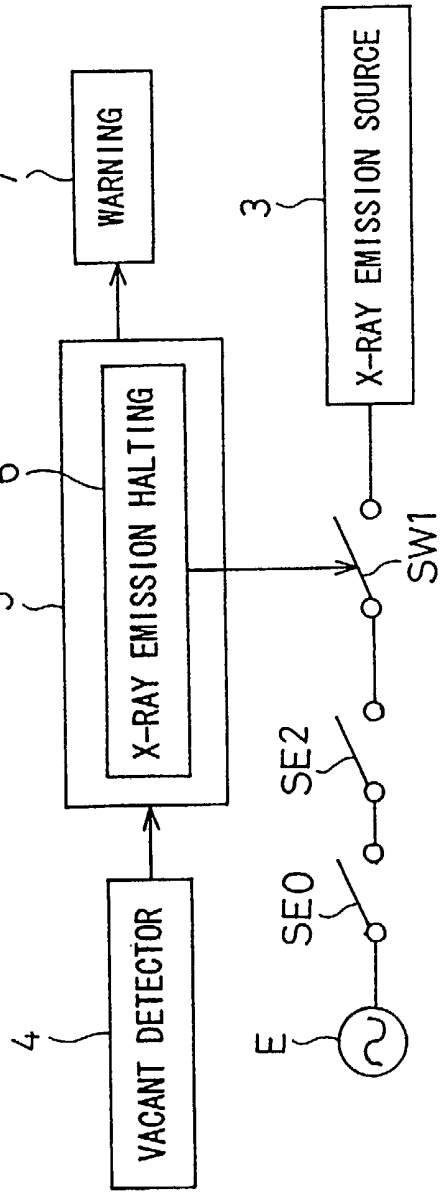
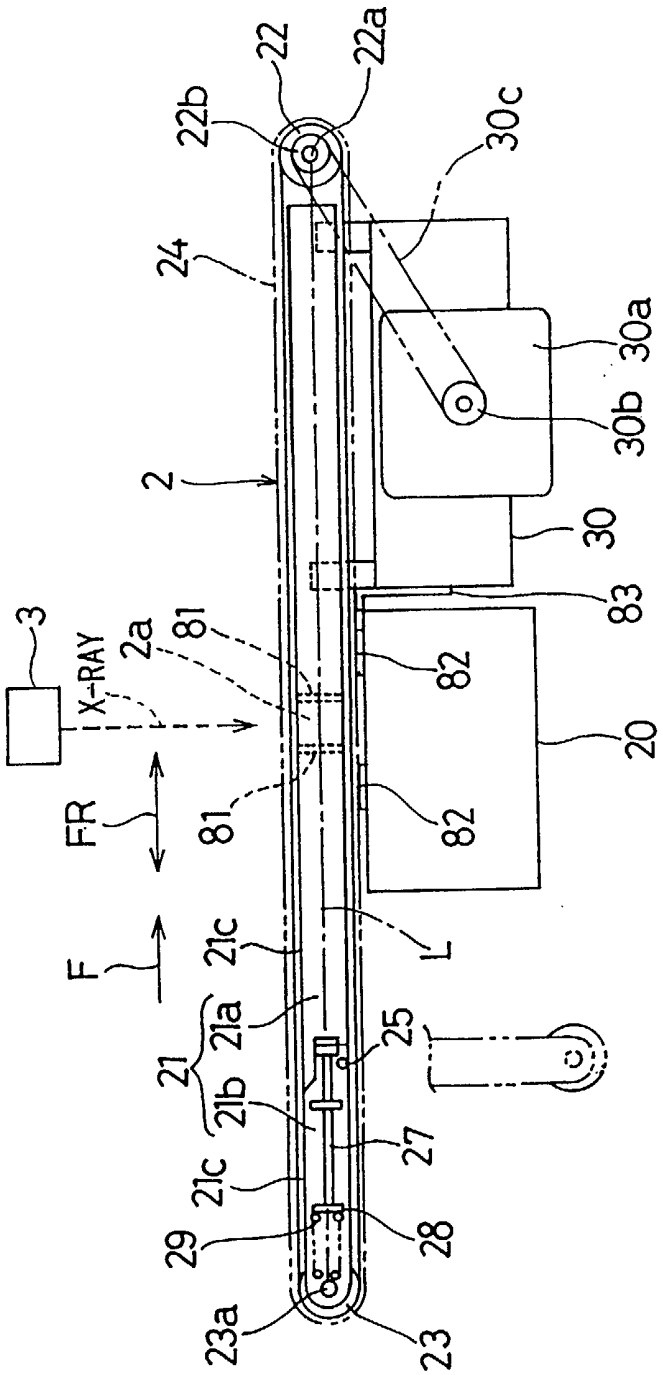

WARNING
7
X-RAY EMISSION SOURCE
3
6
X-RAY EMISSION HALTING
5
SW1
SE2
SE0
E
VACANT DETECTOR
4

Fig. 4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22a
22b
30c
24
30a
30b
2
30
83
3
X-RAY
2a
81
82
20
FR
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82
F
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21
21a
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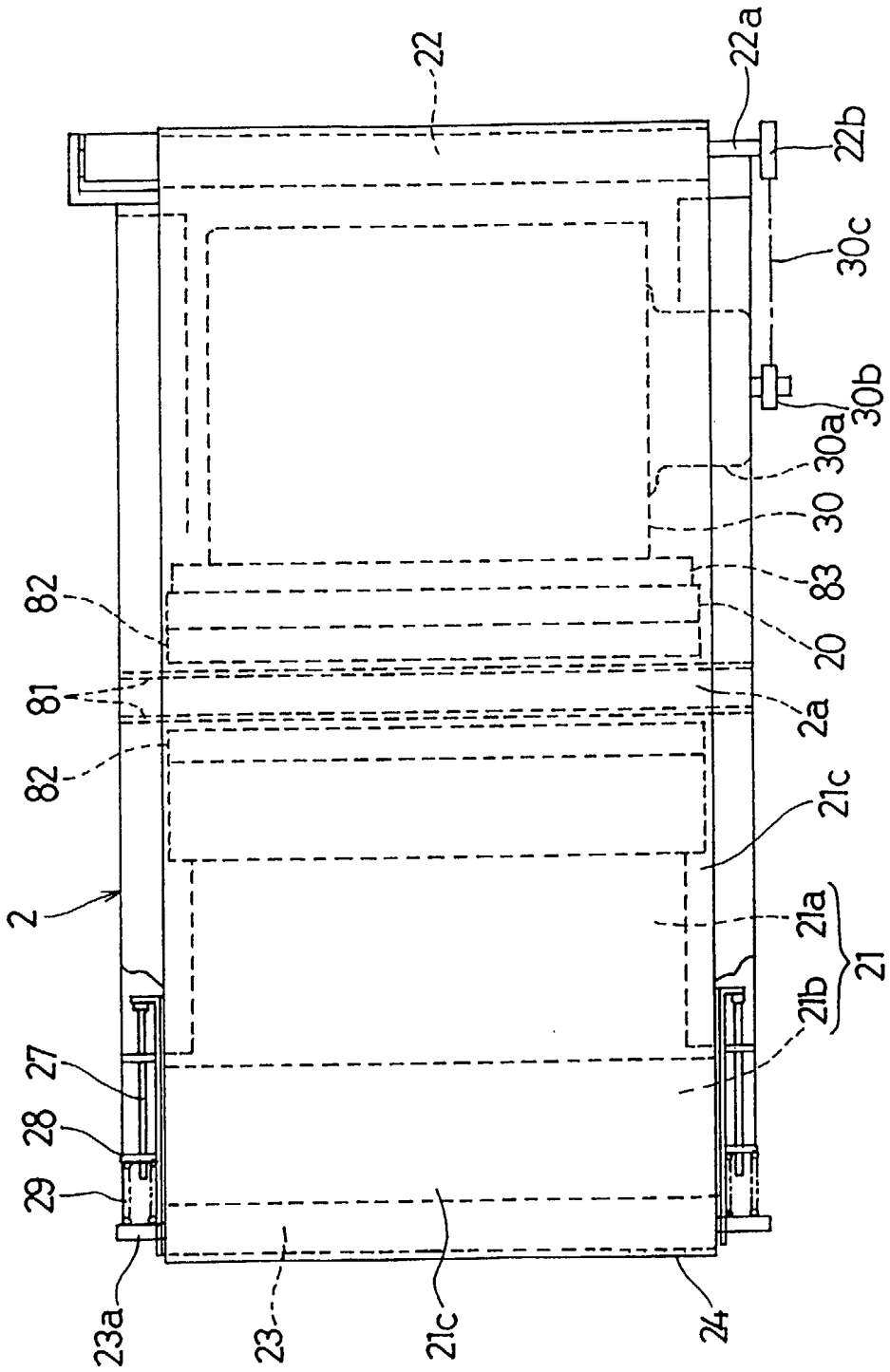
21b
27
21c
29
28
23a
23

Fig. 5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22a
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30c
30b
30a
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20
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21c
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21b
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81
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28
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23a
23
21c
24

Fig. 6

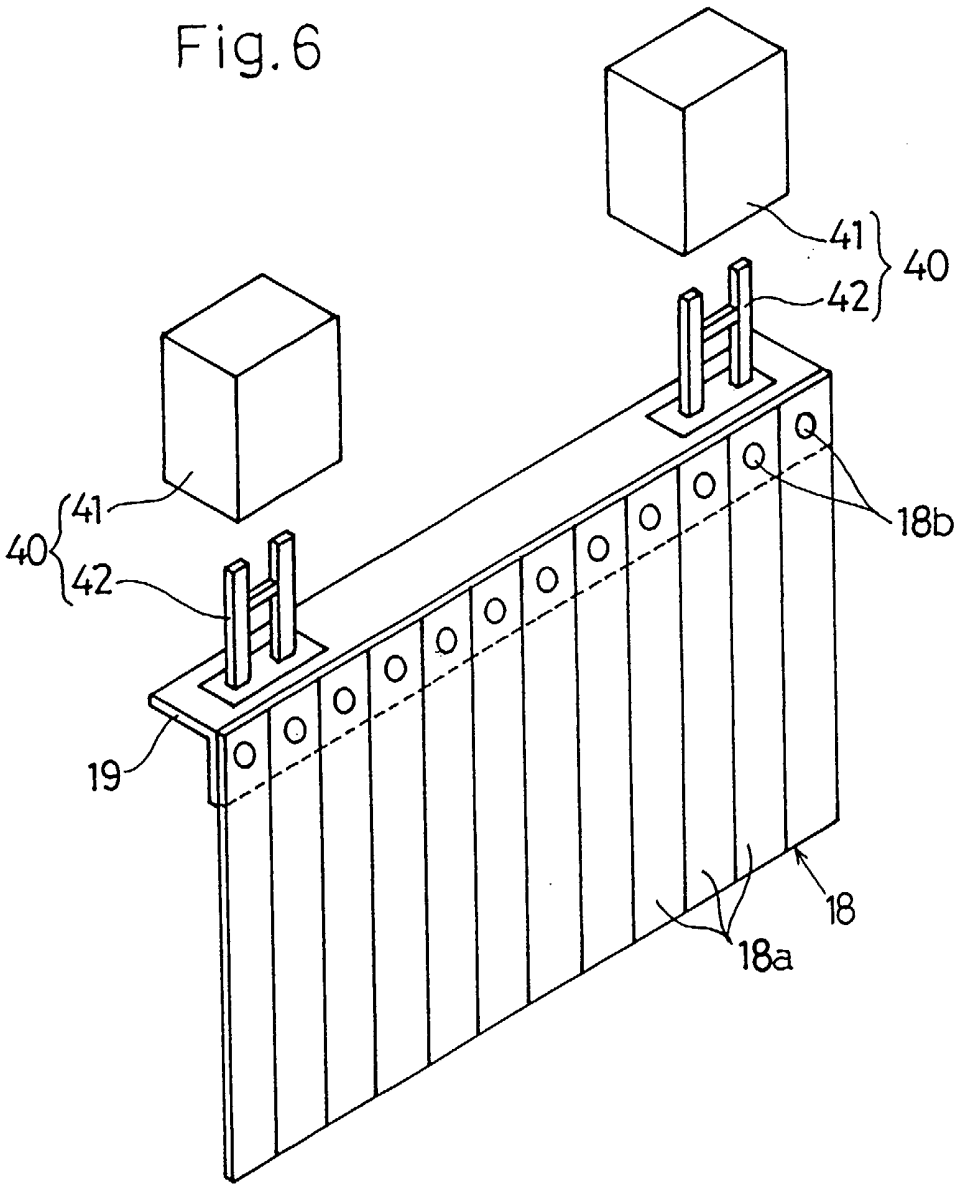

Fig. 7A

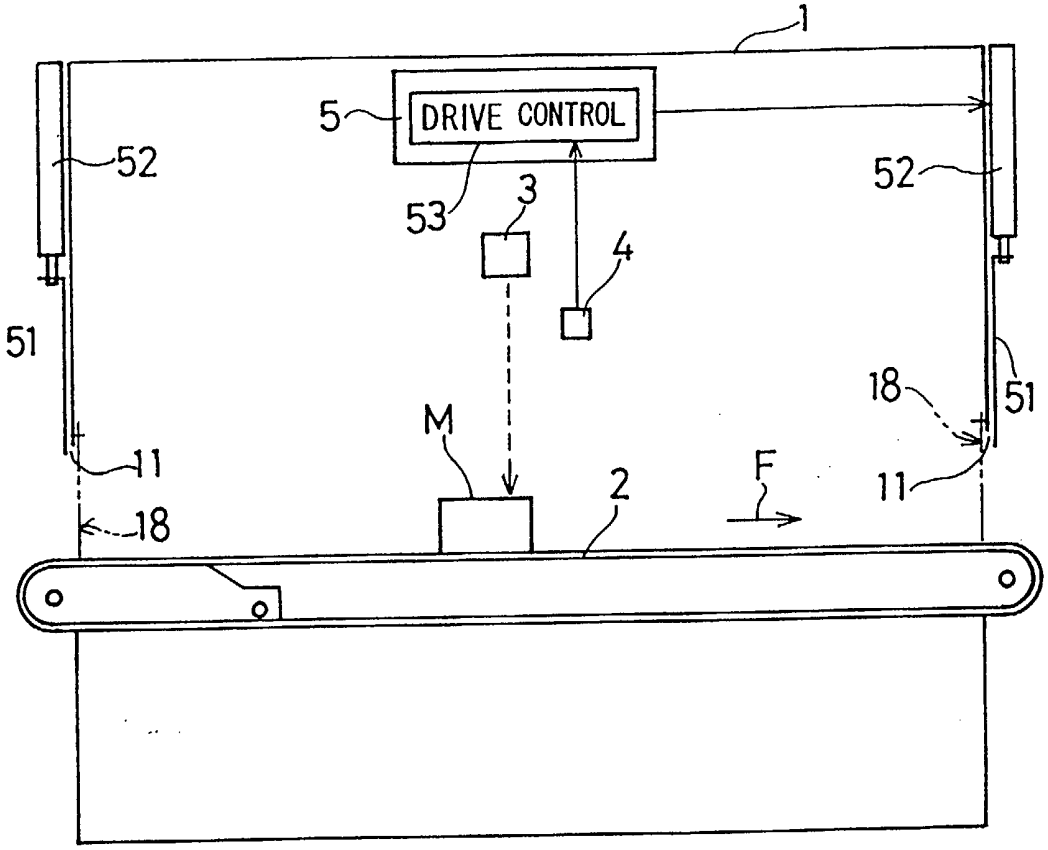

Fig. 7B

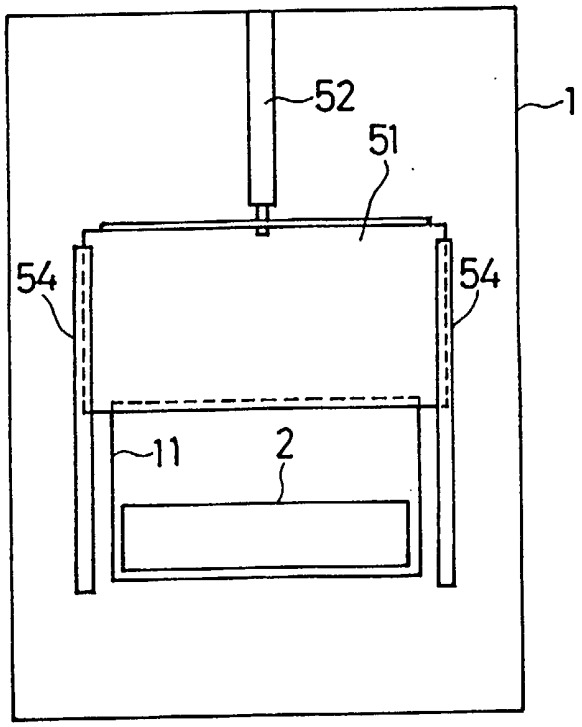

Fig. 7C

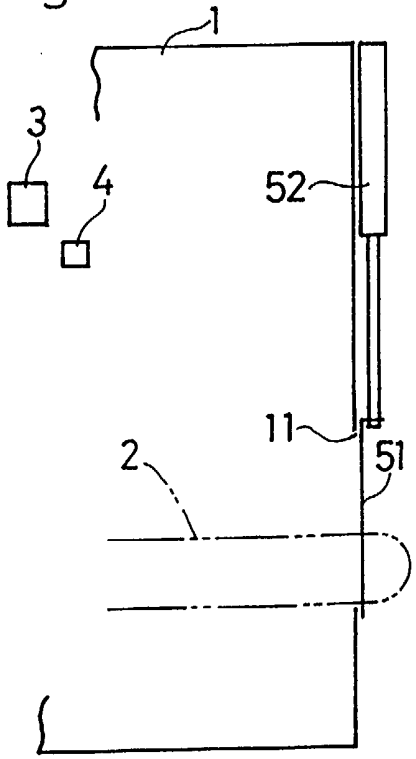

Fig.8A

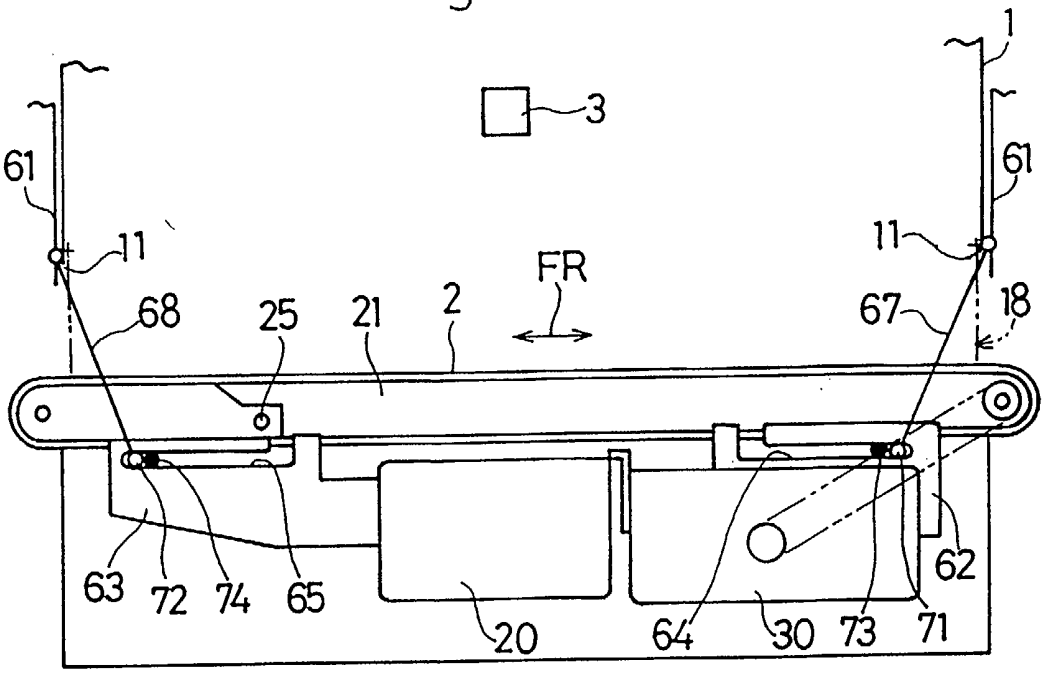
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Fig.8B

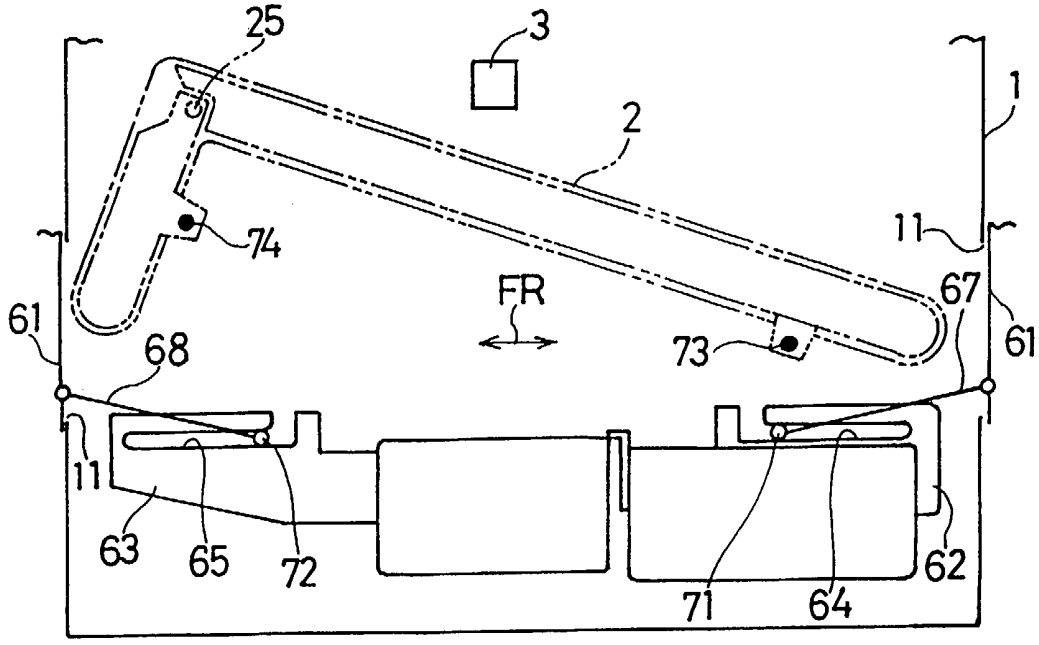
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Fig.9

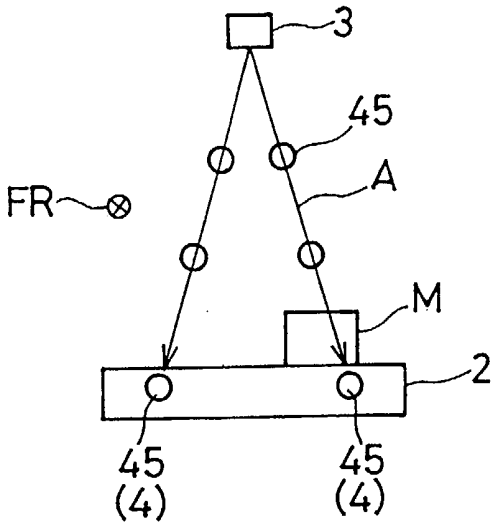
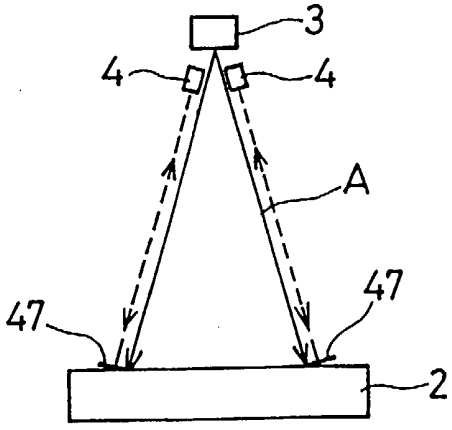


Fig.10



X-ray Foreign Matter Detecting Apparatus

The present invention generally relates to an X-ray foreign matter detecting apparatus for detecting the presence or absence of foreign matter such as, for example, metallic and/or non-metallic particles in an article being inspected.

The prior art X-ray foreign matter detecting apparatus comprises a conveyor housing in which a transport conveyor and an X-ray emission source are accommodated so that X-rays emitted from the X-ray emission source can be applied to the article being transported by the transport conveyor to perform inspection of the article to determine if it contains foreign matter. In the event that the transport conveyor is contaminated, the transport conveyor as a whole or a conveyor belt used therein is removed out of the apparatus so that the transport conveyor or the conveyor belt can be cleansed.

However, it has been found that when the X-ray emission source is erroneously activated while an operator forgets to reset the transport conveyor or the conveyor belt, which had once been removed from the apparatus for cleansing, to the original position and a portion of the apparatus is therefor left open, there is a high possibility that some of the X-rays may leak to the outside of the apparatus through that portion left open.

In view of the foregoing, the present invention is intended to provide an X-ray foreign matter detecting apparatus which is effective to suppress any possible leakage of X-rays from the apparatus to the outside of the apparatus.

In order to accomplish the above described object of the present invention, the present invention in one aspect thereof provides an X-ray foreign

matter detecting apparatus for performing an X-ray inspection of an article by means of X-rays emitted from an X-ray emission source while the article is transported by a transport conveyor. This apparatus includes at least one vacant detector for detecting a non-shielding condition of the apparatus in which at least a portion of the apparatus has been left open and X-rays emitted from the X-ray emission source are not shielded from outside; and an X-ray emission halting means operable in response to detection of the non-shielding condition of the apparatus to halt emission of the X-rays from the X-ray emission source.

In this structure, when that portion of the apparatus is left open and the X-rays emitted from the X-ray emission source are not shielded, the vacant detector detects the non-shielding condition of the apparatus so that the X-ray emission source can be deactivated in response to the output from the X-ray emission halting means then operated in response to the detection of the vacant detector. Accordingly, even though the X-ray emission source is erroneously activated, no X-ray will be generated. Consequently, no X-ray leaks from the open portion to the outside of the apparatus.

In a preferred embodiment of the present invention, an electric power switch that is turned off by the X-ray emission halting means is interposed between the X-ray emission source and an electric power source. This permits the electric power switch to be turned off in response to an output from the X-ray emission halting means based on the vacant detector, to thereby automatically interrupt supply of an electric power to the X-ray emission source. Therefore, any possible leakage of the X-rays can be assuredly prevented, resulting in increase of the reliability of the apparatus.

According to another aspect of the present invention, there is also provided an X-ray foreign matter detecting apparatus for performing an X-ray inspection of an article by means of X-rays emitted from an X-ray emission source while the article is transported by a transport conveyor, which apparatus includes a conveyor housing having first and second openings defined therein in

opposition to each other with respect to a direction of transport of the article. The transport conveyor is removably accommodated within the conveyor housing with its opposite end portions extending outwardly from the conveyor housing through the first and second openings, respectively. At least one vacant detector is employed for detecting opening of the first and second openings by detecting removal of the transport conveyor out of the conveyor housing, in combination with an X-ray shielding shutter provided for each of the first and second openings and operable to close the corresponding opening in response to detection of the opening of the first and second openings.

According to the second mentioned aspect of the present invention, when the openings of the conveyor housing are left open, the vacant detector detects the opening of these openings of the conveyor housing and, based on this, the X-ray shielding shutter closes the openings. Accordingly, even though the X-ray emission source is erroneously switched on, leakage of reflected and/or scattered X-rays from the openings of the conveyor housing can advantageously prevented. Also, since the X-ray shielding shutter is operable to shield, not the X-rays emitted from the X-ray emission source, but the X-rays reflected inside the conveyor housing and being therefore feeble, the X-ray shielding shutter may be sufficiently a thin and simple structure.

The vacant detector may be of a type operable to detect absence of the transport conveyor within the apparatus. The use of this type of the vacant detector is advantageous in that when the operator fails to re-set the transport conveyor once removed out of the conveyor housing and cleansed back to the original position within the conveyor housing, the X-ray emission source is kept automatically halted with no X-ray emitted therefrom. Accordingly, any possible leakage of the X-rays to the outside of the conveyor housing through a space for installation of the transport conveyor can be prevented.

Preferably, the vacant detector is also operable to detect a dropout condition of the article in which at least a portion of the article on the transport

conveyor lies out of a field of coverage of the X-ray emission with respect to a widthwise direction of the transport conveyor, and in such case, a warning means is employed for issuing an alarm in response to detection of the dropout condition of the article. This structure is effective in that not only can the vacant detector be utilized for preventing leakage of the X-rays as described hereinbefore, but also it can be utilized to detect a dropout condition in which at least a portion of the article being transported by the transport conveyor is positioned out of the field of coverage of the X-rays and is not therefore X-ray inspected, during performance of the X-ray inspection to determine if the article contains foreign matter. In the event of detection of the dropout condition of the article, the warning means issues an alarm and, therefore, it is possible to avoid the possibility that the articles having escaped the X-ray inspection may be shipped to the market together with completely inspected and, therefore, acceptable articles.

Preferably, the vacant detector is also operable to detect change of an advance order during change of arrangement in the detecting apparatus. According to this feature, when the article to be inspected is desired to be changed at the time of change of the advance order, the X-ray emission source can be automatically halted in response to depression of an advance order call button effected that time. Accordingly, it is possible not only to avoid unnecessary emission of the X-rays from the X-ray emission source, but also to minimize any possible leakage of the X-rays. In other words, since no article is transported at the time of change of the advance order and no X-ray inspection is also performed, deactivation of the X-ray emission source at this time is effective to avoid unnecessary emission of the X-rays and undesirable leakage of the X-rays to the outside of the conveyor housing.

The present invention in a third aspect thereof provides an X-ray foreign matter detecting apparatus for performing an X-ray inspection of an article by means of X-rays emitted from an X-ray emission source while the

article is transported by a transport conveyor. This apparatus includes a conveyor housing having first and second openings defined therein in opposition to each other with respect to a direction of transport of the article. While the transport conveyor is removably accommodated within the conveyor housing with its opposite end portions extending outwardly from the conveyor housing through the first and second openings, respectively, an X-ray shielding shutter provided for each of the first and second openings is mechanically linked with the transport conveyor to close the corresponding opening in response to removal of the transport conveyor out of the conveyor housing.

With the X-ray foreign matter detecting apparatus according to the third aspect of the present invention, when the first and second openings of the conveyor housing are left open as a result of removal of the transport conveyor out of the conveyor housing, the X-ray shielding shutter is automatically brought to a position in which the first and second openings are closed, in response to removal of the transport conveyor. Accordingly, even though the X-ray emission source is erroneously switched on, leakage of reflected and/or scattered X-rays from the openings of the conveyor housing can advantageously be prevented. Also, since the X-ray shielding shutter is operable shield, not the X-rays emitted from the X-ray emission source, but the X-rays reflected inside the conveyor housing and being therefore feeble, the X-ray shielding shutter may be sufficiently a thin and simple structure.

In a preferred embodiment of the present invention, X-ray shielding members are preferably disposed on respective sides of an X-ray irradiating position with respect to the direction of transport of the article that is defined on the transport conveyor or below the transport conveyor. These X-ray shielding members are operable to suppress leakage of the X-rays in a direction forwardly and rearwardly with respect to the direction of transport. The use of the X-ray shielding members is effective to suppress leakage of the X-rays in respective

directions forwardly and rearwardly of the X-ray irradiating position during inspection of the article with the X-rays applied thereto.

In another preferred embodiment of the present invention, a drain vat for collecting rinsing water is preferably positioned below the transport conveyor and inclined downwardly with respect to a horizontal level, in combination with a downwardly inclined shielding plate positioned above a scupper defined in the drain vat for discharge of the rinsing water outwardly from the drain vat, for shielding the scupper from the X-rays. According to this feature, water used to cleanse the interior of the conveyor housing is collected in the drain vat and is then discharged to the outside of the conveyor housing through the scupper. When the scupper is open towards the outside of the conveyor housing, the downwardly inclined shielding plate positioned adjacent the scupper is effective to suppress leakage of the X-rays and/or scattering rays outwardly through the scupper.

In the accompanying drawings, like reference numerals are used to denote like parts throughout the several views, and:

Fig. 1 is a perspective view of an X-ray foreign matter detecting apparatus according to a first preferred embodiment of the present invention;

Fig. 2 is a schematic front elevational view of the X-ray foreign matter detecting apparatus shown in Fig. 1;

Fig. 3 is a circuit block diagram of a control unit for controlling an X-ray emission source with detectors;

Fig. 4 is a side view of a transport conveyor used in the X-ray foreign matter detecting apparatus shown in Fig. 1;

Fig. 5 is a top plan view of the transport conveyor shown in Fig. 4;

Fig. 6 is a perspective view of one of flexible X-rays shielding curtains employed in the X-ray foreign matter detecting apparatus;

Fig. 7A is a schematic side view of the X-ray foreign matter detecting apparatus according to a second preferred embodiment of the present invention;

Fig. 7B is a front elevational view of the X-ray foreign matter detecting apparatus shown in Fig. 7A;

Fig. 7C is a fragmentary side view of a portion of the X-ray foreign matter detecting apparatus illustrating an operation thereof;

Fig. 8A is a schematic side view of the X-ray foreign matter detecting apparatus according to a third preferred embodiment of the present invention;

Fig. 8B is a side view of the X-ray foreign matter detecting apparatus illustrating an operation thereof;

Fig. 9 is a schematic front elevational view showing a modified form of vacant detectors employed in the X-ray foreign matter detecting apparatus; and

Fig. 10 is a schematic front elevational view showing a further modified form of vacant detectors employed in the X-ray foreign matter detecting apparatus.

Hereinafter, preferred embodiments of the present invention will be described with reference to the accompanying drawings.

Fig. 1 illustrates, in a schematic perspective representation, an entire structure of an X-ray foreign matter detecting apparatus according to a first preferred embodiment of the present invention. This detecting apparatus includes an upright conveyor housing 1 having a longitudinal axis extending in a heightwise direction thereof, a single bendable transport conveyor 2 positioned generally intermediate of the height of the conveyor housing 1 and extending so as to traverse the interior of the conveyor housing 1, and an X-ray emission source 3 accommodated within the conveyor housing 1 and positioned at a location above the transport conveyor 2 and intermediate of the width of the transport conveyor 2 for irradiating articles M, then successively transported by

the transport conveyor 2 beneath the X-ray emission source 3 for detecting the presence or absence of foreign matter such as, for example, metallic and/or non-metallic particles in the article M. The transport conveyor 2 is used to transport the articles M successively in a forward direction shown by the arrow F and has a length greater than the length of the conveyor housing 1 as measured in a direction forwardly and rearwardly of the conveyor housing 1 as shown by the arrow FR. This transport conveyor 2 is detachably mounted in the conveyor housing 1 with its opposite ends protruding outwardly from a first and second openings, or conveyor openings 11 provided at front and rear walls of the conveyor housing 1.

The conveyor housing 1 has left and right side walls opposite to each other and has an takeoff opening 12 defined in the left side wall so that the transport conveyor 2 as a whole can be removed out of the conveyor housing 1 through such takeoff opening 12. An X-ray shielding door 13 is hinged to the left side wall so as to selectively open and close the takeoff opening 12. In Fig. 1, reference numeral 5 represents a controller for the entire apparatus, reference numeral 16 represents a touch panel display for displaying and inputting, one at a time, during inspection being performed to determine the presence or absence of the foreign matter, and reference numeral 17 represents a display for displaying a radioscopic image. Reference numeral 18 represents a lead-containing flexible X-ray shielding curtain of a slit configuration formed by a plurality of flexible curtain strips 18a and secured to front and rear walls of the conveyor housing 1 so as to cover the conveyor openings 11 defined in the front and rear walls of the conveyor housing 1. Fig. 2 illustrates a front elevational view of the detecting apparatus shown in Fig. 1. When the transport conveyor 2 is not set in position, that is, when the transport conveyor 2 is removed from a predetermined position of installation thereof within the conveyor housing 1 for servicing or replacement, a portion of the conveyor housing 1, for example, that portion of the conveyor housing 1 below the transport conveyor 2, is left vacant enough to

allow the X-rays to leak to the outside of the conveyor housing 1 with the conveyor housing 1 brought in a non-shielding condition with respect to the X-rays . In view of this, a vacant detector 4 such as, for example, a laser sensor or an infrared sensor of a distance measuring type for detecting the non-shielding condition of the conveyor housing 1 is disposed above the transport conveyor 2 then set in within the conveyor housing 1, more specifically above the position of installation of the transport conveyor 2. This vacant detector 4 detects the non-shielding condition of the conveyor housing 1 in terms of the detection distance detected during the absence or removal of the transport conveyor 2 (i.e., the distance from the position of the vacant detector 4 to a structural member positioned below the position where the transport conveyor 2 ought to occupy) which is longer than the detection distance detected during the presence of the transport conveyor 2 within the conveyor housing 1 (i.e., the distance from the position of the vacant detector 4 to the transport conveyor 2). The vacant detector 4 issues a detection signal indicative of the non-shielding condition of the conveyor housing 1, which is in turn used to automatically forcibly halt emission of the X-rays from the X-ray emission source 3. In the illustrated embodiment, two vacant detectors 4 of the kind discussed above are employed and positioned above opposite side edge portions of the transport conveyor 2 which are clear from the field of coverage A of the X-rays emitted from the X-ray emission source 3, so that the vacant detectors 4 can detects the non-shielding condition in which the transport conveyor 2 has been removed from the conveyor housing 1. It is to be noted that the field of coverage A of the X-rays when viewed in a direction conforming to the direction forwardly and rearwardly of the conveyor housing 1 as shown by the arrow FR, depicts a shape of the triangle whose base lies on an upper surface of the transport conveyor 2.

Each of the vacant detectors 4 referred to above concurrently serves to detect a dropout condition in which at least a portion of one or more articles M being transported by the transport conveyor 2 is positioned out of the field of

coverage A of the X-rays and is not therefore X-ray inspected. Detection of the dropout condition is possible in view of the fact that the detection distance measured by the vacant detector 4 becomes shorter than that of the transport conveyor 2. An X-ray detector 20 for detecting the X-rays emitted from the X-ray emission source 3 is disposed immediately below the X-ray emission source 3 and at a location beneath the transport conveyor 2.

Fig. 3 illustrates a block circuit diagram of a control section for controlling the X-ray emission source 3 with the vacant detector 4. As shown therein, a controller 5 is provided with an X-ray emission halting means 6 and has an input stage connected with the vacant detector 4 and an output stage connected with a warning means 7 such as, for example, a buzzer for generating a warning in the event that the vacant detector 4 detects the dropout condition discussed above. For this warning means 7, alternatively or in combination with the buzzer, the display 17 for displaying a radioscopic image may be utilized provided that the display 17 can blink in response to a detection signal outputted from the controller 5 to call an operator's attention. Also, a power switch SW1 is interposed between the X-ray emission source 3 and an electric power source E so that the power switch SW1 can be controlled by the X-ray emission halting means 6 of the controller 5.

In the event that the vacant detector 4 detects the non-shielding condition of the conveyor housing 1, the power switch SW1 can be turned off through the X-ray emission halting means 6 of the controller 5 with the supply of an electric power from the electric power source E to the X-ray emission source 3 consequently directly interrupted automatically. In other words, assuming that the transport conveyor 2 once removed from the conveyor housing 1 for, for example, cleansing purpose while a manually operable or automatically operable main switch SW0 had been turned off to deactivate the X-ray emission source 3 is, after it has been cleansed, re-set in position within the conveyor housing 1, and even when the main switch SW0 is subsequently turned on while the

operator having forgotten that the cleansed transport conveyor 2 was re-set in position within the conveyor housing 1, the X-ray emission source 3 can be deactivated in response to an output from the X-ray emission halting means 6 that is generated based on the vacant detector 4. Accordingly, leakage of the X-rays to the outside of the conveyor housing 1 through the conveyor openings 11 and any other openings can be eliminated advantageously.

In the event that during the X-ray inspection taking place with the article M being transported by the transport conveyor 2 at least a portion of the article M is in the dropout condition in which no X-ray inspection cannot be effected to that portion of the article M because of that portion of the article M moving out of the field of coverage A of the X-rays on the transport conveyor 2, the dropout condition of the article M can be detected by the vacant detector 4. When this vacant detector 4 detects the dropout condition of the article M, the warning means 7 is triggered by an output from the controller 5 to issue a warning and, therefore, it is possible to avoid the possibility that the articles having escaped the X-ray inspection may be shipped to the market together with completely inspected and, therefore, acceptable articles. In place of or in combination with this warning means 7, another warning means for providing an indication of detection of the dropout condition of the article M may be employed.

According to the embodiment shown in Figs. 1 to 3, a door switch SW2 is inserted between the X-ray emission source 3 and the electric power source E and positioned on one side of the power switch SW1 adjacent the electric power source E, that is, between the main switch SW0 and the power switch SW1. This door switch SW2 is used for detecting opening or closing of the X-ray shielding door 13 so that when the X-ray shielding door 13 is opened the door switch SW2 can be turned off to automatically interrupt supply of an electric power from the electric power source E to the X-ray emission source 3 without relying on the controller 5.

Also, the vacant detector 4 may be of a type capable of detecting manipulation of an operating button that is manipulated when an advance order is to be changed at the time of change of arrangement. According to this, in the event that, for example, a product to be inspected is changed at the time of change of the advance order, the X-ray emission source 3 can be automatically deactivated. More specifically, depression of an advance order call button results in deactivation of the X-ray emission source 3. Also, depression of a run button provided on the display 16 (Fig. 1) results in emission of the X-rays resumed by the X-ray emission source 3. Because of this, not only can unnecessary emission of the X-rays from the X-ray emission source 3 be avoided, but leakage of the X-rays can also be eliminated. In other words, since at the time of change of the advance order no article M is transported and, hence, no X-ray inspection of the article M is performed, deactivation of the X-ray emission source 3 at this time is effective to avoid the unnecessary emission of the X-rays and also the leakage of the X-rays to the outside of the conveyor housing 1.

Fig. 4 is a side view of the transport conveyor 2 and Fig. 5 is a top plan view thereof. The transport conveyor 2 includes a conveyor framework 21, a drive roller 22 supported by one end of the conveyor framework 21 by means of a drive shaft 22a, a driven roller 23 supported by the opposite end of the conveyor framework 21 by means of a driven shaft 23a, and a transport belt 24 in the form of an endless flat belt trained between the drive and driven rollers 22 and 23. The conveyor framework 21 is made up of a generally elongated frame body 21a and a short frame piece 21b provided at a rear end thereof. The short frame piece 21b is supported by a bending support shaft 25 extending in a direction leftwards and rightwards of the frame body 21a for bending up and down about the bending support shaft 25. A drive unit 30 including a power source 30a such as, for example, a drive motor is disposed at a front lower region of the flat belt 24, and an endless belt 30c is trained between a drive wheel 30b,

provided in the drive unit 30, and a drive wheel 22b provided on the drive shaft 22a so that the flat belt 24 can be driven through a drive shaft 23a. In the illustrated embodiment, a ceiling member 21c is disposed above the frame body 21a and the short frame piece 21b in face-to-face relation with an inner surface of the flat belt 24.

Also, in the illustrated embodiment, the driven shaft 23a of the driven roller 23 is supported for movement relative to the short frame piece 21b in a direction lengthwise of the transport conveyor, that is, in a direction conforming to the direction forwardly and rearwardly of the transport conveyor housing 1 as shown by the arrow FR. A screw rod 27 disposed on each side of the transport conveyor framework 21 is freely rotatably fitted to the short frame piece 21b and threaded to a plate member 28. A spring member 29 for urging the driven roller 23 in an outward direction, that is, in the direction rearwardly of the transport conveyor housing 1 is employed on each side of the transport conveyor frame work 21 and is interposed between the plate member 28 and the driven shaft 23a. Accordingly, when the screw rod 27 is turned to move the plate member 28 relative to the short frame piece 21b in the direction forwardly and rearwardly of the transport conveyor housing 1, the driven roller 23 can be correspondingly moved in such direction through the springs 29 so that the span between the driven roller 23 and the drive roller 22 can be adjusted. As a result thereof, even though the flat belt 24 has a varying length or slackened, the flat belt 24 can be held under tension at all times to facilitate a smooth and stable transport of the articles M.

The bending support shaft 25 is positioned below an imaginary straight line L that connects respective axes of rotation of the drive and driven rollers 22 and 23 when the frame body 21a and the short frame piece 21b are rectilinearly aligned with each other. By so doing, when the frame body 21a and the short frame piece 21b are rectilinearly aligned with each other as shown in Fig. 4, the short frame piece 21b has a tendency to bend upwardly about the

bending support shaft 25 by the effect of a resilient restoring force exerted by the flat belt 24. However, the short frame piece 21b is brought into contact with the ceiling member 21c rigid with the frame body 21a to thereby prevent the short frame piece 21b from being bent upwardly about the bending support shaft 25. Also, since the bending support shaft 25 is positioned below the level of the respective axes of rotation of the drive and driven rollers 22 and 23, the short frame piece 21b does not bend downwardly about the bending support shaft 25. Accordingly, by the effect of the resilient restoring force of the flat belt 24, the frame body 21a and the short frame piece 21b are stably held in a straight position in which they are rectilinearly aligned with each other, thereby ensuring a successive forward transport of the articles M.

When and while inspection is performed to determine the presence or absence of foreign matter in each of the articles M, the frame body 21a and the short frame piece 21b are held in the straight position having been rectilinearly aligned with each other and the flat belt 24 trained between and around the drive and driven rollers 22 and 23, the transport conveyor 2 can be set in position inside the conveyor housing 1 as shown in Fig. 1. With the transport conveyor 2 so set inside the conveyor housing 1, the X-ray emission source 3 irradiates the articles M being successively transported by the transport conveyor 2 while resting on the flat belt 24 to perform an X-ray inspection to determine the presence or absence of the foreign matter in each of the articles M.

In the event that the transport conveyor 2 is desired to be removed out of the conveyor housing 1 for cleansing thereof, the short frame piece 21b has to be bent downwardly about the bending support shaft 25 relative to the frame body 21a as shown by the phantom line in Fig. 4 so that the length of the transport conveyor 2 can be in effect reduced to a value smaller than the width of the takeout opening 12, defined in the left side wall of the conveyor housing 1 as shown in Fig. 1, as measured in a direction conforming to the forward and rearward direction FR. With the short frame piece 21b so bent downwardly

relative to the frame body 21a, the transport conveyor 2 as a whole can easily and smoothly be removed out of the conveyor housing 1 through the takeout opening 12 by adjustably moving the transport conveyor 2 as a whole in a direction conforming to the forward and rearward direction FR. Resetting of the transport conveyor 2 into the conveyor housing 1 can also be performed easily and smoothly in a manner reverse to the removal therefrom from the conveyor housing 1 described above. Specifically, the cleansed transport conveyor 2 with the short frame piece 21b bent downwardly relative to the frame body 21a has to be introduced into the conveyor housing 1 through the takeout opening 12, followed by pivoting the short frame piece 21b upwardly about the bending support shaft 25 relative to the frame body 21a so to allow the frame body 21a and the short frame piece 21b to assume the straight position.

In the embodiment shown in Figs. 4 and 5, two first X-ray shielding members 81 and 81 for suppressing leakage of X-rays and/or scattering rays in opposite directions conforming to the forward and rearward direction FR are fitted to the frame body 21a so as to extend a distance corresponding to the full width of the transport conveyor 2. The first X-ray shielding members 81 and 81 are positioned forwardly and rearwardly, respectively, of an X-ray penetrating portion 2a defined at a position of travel of X-rays from the X-ray emission source 3, which is in turn defined at a location generally intermediate of the length of the frame body 21a of the transport conveyor 2. Two second X-ray shielding members 82 and 82 for suppressing leakage of the X-rays and/or scattering rays in opposite directions conforming to the forward and rearward direction FR are also fitted so as to extend a distance corresponding to the full width of the transport conveyor 2 and positioned on top of the X-ray detector 20 and at respective locations forwardly and rearwardly, respectively, of the X-ray penetrating portion defined at the position of travel of the X-rays.

A third X-ray shielding member 83 of a generally L-shaped configuration which concurrently serves as a bracket for securing a rear end of

the drive unit 30 to the frame body 21a is fitted in position between the X-ray detector 20 and the drive unit 30 for suppressing leakage of the X-rays and/or scattering rays in the forward and rearward direction FR. Each of the first to third shielding members 81 to 83 is in the form of a plate made of, for example, stainless steel excellent in X-ray shielding effect. The use of the first to third X-ray shielding plates 81 to 83 is effective to suppress leakage of X-rays, emitted from the X-ray emission source 3, and/or scattering rays developed as a result of impingement of the X-rays upon surrounding portions, in all directions during inspection of the articles M one at a time using the X-rays emitted from the X-ray emission source 3.

Referring again to Fig. 2, a drain vat 9 is positioned below the transport conveyor 2 within the conveyor housing 1 so as to extend in a leftward and rightward direction perpendicular to the direction of transport of the articles M. This drain vat 9 is supported so as to incline with its left-hand portion thereof positioned at a level lower than a right-hand portion thereof as viewed in Fig. 2 and has a downwardly opening scupper 91 defined at the lowest level portion of the bottom of the drain vat 9. An additional X-ray shielding plate 92 for shielding X-rays, which would leak through the scupper 91 is disposed above the scupper 91 so as to incline rightwardly downwardly. Water used to cleanse the interior of the conveyor housing 1 is collected in the drain vat 9 and is then discharged to the outside of the conveyor housing 1 through the scupper 91. While the scupper 91 is open towards the outside of the conveyor housing 1 at all times or only during cleansing, the additional shielding plate 92 positioned adjacent the scupper 91 is effective to suppress leakage of the X-rays and/or scattering rays outwardly through the scupper 91.

The manner in which each of the flexible X-ray shielding curtains 18 of a slit configuration is secured to the front or rear wall of the conveyor housing 1 so as to cover the corresponding conveyor opening 11 is shown in a perspective view in Fig. 6. Each flexible X-ray shielding curtain 18 is made up of a

plurality of flexible curtain strips 18a each containing lead. These flexible curtain strips 18a are secured at one end to a transverse frame 19 by means of a corresponding number of fastening elements 18b such as, for example, set screws in side-by-side relation to each other in a direction lengthwise of the transverse frame 19. The transverse frame 19 forms a part of the conveyor housing 1 and extends in the widthwise direction of the conveyor housing 1. Two vacant detectors 40 are interposed between the transverse frame 19 and the associated side edge portion of the conveyor opening 11 (Fig. 1) for detecting detachment of the respective flexible X-ray shielding curtain 18 from the right position. The vacant detector 40 concurrently serves as means for securing the flexible X-ray shielding curtain 18 to the front or rear wall of the conveyor housing 1 so as to cover the corresponding conveyor opening 11.

In the illustrated embodiment, each of the vacant detectors 40 is employed in the form of a limit switch assembly made up of male and female switches 41 and 42 with the female switch 41 and the male switch 42 secured respectively to the front or rear wall of the conveyor housing 1 and the transverse frame 19. The respective flexible X-ray shielding curtain 18 made up of the flexible curtain elements 18a is detachably secured to the front or rear wall of the conveyor housing 1 through the paired switches 41 and 42. Thus, the limit switch assemblies 40 concurrently serve as support members for supporting each of the flexible X-ray shielding curtains 18 relative to the front or rear wall of the conveyor housing 1 so as to cover the associated conveyor opening 11.

The vacant detectors 40 are electrically connected with the power switch SW1 in a manner similar to those described hereinbefore through the X-ray emission halting means 6 of the controller 5 shown in Fig. 3. Accordingly, in the event that at least one of the flexible X-ray shielding curtains is separated from the right position in which it covers the corresponding conveyor opening 11, the X-ray emission source 3 can be automatically deactivated in response to an output from the X-ray emission halting means 6

based on the corresponding vacant detector 40, thereby preventing the X-rays from leaking through the conveyor opening 11 to the outside of the conveyor housing 1.

Figs. 7A to 7C illustrate a second preferred embodiment of the present invention. In this second embodiment, arrangement has been made so that when the transport conveyor 2 is removed out of the conveyor housing 1, the conveyor openings 11 and 11 positioned along the transport path of the transport conveyor 2 can be closed by respective X-ray shielding shutters 51. Referring specifically to Fig. 7A, each of the front and rear walls of the conveyor housing 1 is provided with the X-ray shielding shutters 51 for selectively closing the associated conveyor opening 11 and a shutter drive mechanism 52 such as, for example, a pneumatically operated cylinder for driving the respective X-ray shielding shutter 51 between opened and closed positions.

In the event that the transport conveyor 2 is removed out of the conveyor housing 1 in the manner as hereinbefore discussed, lower regions of the flexible X-ray shielding curtains each made up of the flexible curtain strips 18, which have been occupied by respective spaced apart portions of the transport conveyor 2, are left open enough to allow the X-rays to leak to the outside of the conveyor housing 1. Accordingly, in response to output signals from the vacant detectors 4 indicative of the opening of the lower regions of the associated flexible X-ray shielding curtains, a drive control means 53 included in the controller 5 activates the shutter drive mechanisms 52 to drive the respective X-ray shielding shutters 51 to descend down to the closed positions to thereby close the conveyor openings 11. Movement of each of the X-ray shielding shutters 51 along the corresponding wall of the conveyor housing 1 between the opened and closed positions is guided by left and right guide members 54 secured to the front or rear wall of the conveyor housing 1 as shown in Fig. 7B.

According to the second embodiment of the present invention, as shown in Fig. 7C, when the transport conveyor 2 is removed out of the conveyor

housing 1, the vacant detectors 4 detects opening of the conveyor openings 11 and the X-ray shielding shutters 51 are then lowered to close the conveyor openings 11. Accordingly, even though the X-ray emission source 3 is erroneously or accidentally turned on to emit X-rays, it is possible to prevent the X-rays, emitted from the X-ray emission source 3 and then reflected and/or scattered inside the conveyor housing 1, from leaking to the outside of the conveyor housing 1 through the conveyor openings 11. Also, since the X-ray shielding shutters 51 when moved to the closed position shield not the X-rays emitted from the X-ray emission source 3, but the X-rays reflected inside the conveyor housing 1 and being therefore feeble, each of the X-ray shielding shutters 51 may be sufficiently a thin and simple structure.

Figs. 8A and 8B illustrate a third preferred embodiment of the present invention, in which arrangement has been made so that when the transport conveyor 2 is removed out of the conveyor housing 1, the conveyor openings 11 can be closed by respective X-ray shielding shutters 61 that are mechanically drivingly associated with removal of the transport conveyor 2.

Referring now to Fig. 8A, the front and rear walls of the conveyor housing 1 are provided with respective front and rear X-ray shielding shutters 61 for closing the associated conveyor openings 11 and, on the other hand, a front guide member 62 for guiding the front X-ray shielding shutter 61 so as to move up and down along the front wall of the conveyor housing 1 is mounted on the drive unit 30 that is positioned below the transport conveyor 2 while a rear guide member 63 for guiding the rear X-ray shielding shutter 61 so as to move up and down along the rear wall of the conveyor housing 1 is mounted on the X-ray detector 20. Each of the front and rear guide members 62 and 63 is formed with a guide portion 64 or 65 in the form of a guide groove. Specifically, the front guide groove 64 defined in the front guide member 62 includes a horizontally extending groove portion and a vertically extending groove portion continued from a rear end of the horizontally extending guide portion and lying

perpendicular thereto, whereas the rear guide groove 65 defined in the rear guide member 63 includes a horizontally extending groove portion and a vertically extending groove portion continued from a front end of the horizontally extending guide portion and lying perpendicular thereto.

The front and rear X-ray shielding shutters 61 are pivotally coupled with respective link members 67 and 68. While one end of each of the link members 67 and 68 is pivotally connected to the associated X-ray shielding shutter 61, the opposite end thereof has an engagement portion 71 or 72 that is engaged in the horizontally extending groove portion of the corresponding guide groove 64 or 65 for movement in a direction conforming to the forward and rearward direction FR. The conveyor framework 21 of the transport conveyor 2 has front and rear end portions provided with respective front and rear pusher members 73 and 74 which are, when the frame body 21a and the short frame piece 21b are held in the straight position as shown in Fig. 7A, slidably engaged in the associated horizontally extending groove portions of the front and rear guide grooves 64 and 65 and positioned rearwardly of the front engagement portion 71 and forwardly of the rear engagement portion 72. Accordingly, the front and rear X-ray shielding shutters 61 can be pushed upwardly and retained at an open position for opening the conveyor openings 11 when the engagement portions 71 and 72 are pushed forwardly and rearwardly in contact with and by the front and rear pusher members 73 and 74.

Starting from the condition described above and shown in Fig. 8A, when the transport conveyor 2 is bent about the bending support shaft 25 as shown by the double-dotted phantom line in Fig. 8B in a manner similar to that described in connection with the first embodiment of the present invention, with the pusher members 73 and 74 disengaged from the associated guide grooves 64 and 65 by way of the vertically extending groove portions thereof, the engagement portions 71 and 72 are slid in the associated guide grooves 64 and 65 in respective rearward and forward directions counter to each other, until the

X-ray shielding shutters 61 assume the closed position to close the corresponding conveyor openings 11 as shown in Fig. 8B. Rearward movement of the engagement portion 71 within and along the guide groove 64 is effected by the total weight of the front X-ray shielding shutter 61 and the associated link member 67 whereas forward movement of the engagement portion 72 within and along the guide groove 65 is effected by the total weight of the rear X-ray shielding shutter 61 and the associated link member 67 and 68.

According to the third embodiment of the present invention, when the transport conveyor 2 is removed out of the conveyor housing 1 with the conveyor openings 11 consequently tending to be opened, the X-ray shielding shutters 61 close the associated conveyor openings 11 in a fashion mechanically associated with the removal of the transport conveyor 2. Accordingly, even though the X-ray emission source 3 is erroneously or accidentally turned on to emit X-rays, it is possible to prevent the X-rays, emitted from the X-ray emission source 3 and then reflected and/or scattered inside the conveyor housing 1, from leaking to the outside of the conveyor housing 1 through the conveyor openings 11. Also, since the X-ray shielding shutters 61 when moved to the closed position shield not the X-rays emitted from the X-ray emission source 3, but the X-rays reflected inside the conveyor housing 1 and being therefore feeble, each of the X-ray shielding shutters 61 may be sufficiently a thin and simple structure.

In the third embodiment of the present invention, although the X-ray shielding shutters 61 has been operatively associated with removal of the transport conveyor 2 to close the conveyor openings 11, arrangement may be made so that the X-ray shielding shutters can be operatively associated with removal of the flexible X-ray shielding curtains 18 that are positioned above the transport conveyor 2 so as to cover the conveyor openings 11, respectively. In such case, the X-ray shielding shutters similar to the X-ray shielding shutters 61 shown in Fig. 8A are to be disposed adjacent the associated conveyor openings 11. Also, guide grooves similar to the guide grooves 64 and 65 shown in Figs.

8A and 8B have to be provided above the conveyor openings 11 and vacant detectors similar to the vacant detectors 40 shown in Fig. 6 that are used to support the flexible X-ray shielding curtains 18, respectively, have to be disposed deep in the associated guide grooves with their detachment mouths oriented inwardly of the conveyor housing 1 in a direction conforming to the forward and rearward direction FR, and the female and male switches 41 and 42 provided on the curtain frame 19 supporting the X-ray shielding curtains 18 are detachably provided in the vacant detectors 40, respectively. Also, link members similar to the link members 67 and 68 shown in Figs. 8A and 8B have their one ends coupled with the flexible X-ray shielding curtains 18 and have their opposite ends provided with the engagement portions 71 and 72, and the pusher members 73 and 74 provided on the curtain frame 19 are engaged in the guide grooves so as to sandwich the engagement portions 71 and 72 that are engaged in the guide grooves, to thereby mount the female and male switches 41 and 42 on the vacant detectors 40, respectively. According to this structure, when the flexible X-ray shielding curtains 18 are removed from the conveyor openings 11, the X-ray shielding shutters 61 descend by the effect of their own weight to thereby close the conveyor openings 11 and, accordingly, even though the X-ray emission source 3 is erroneously or accidentally switched on, it is possible to prevent the X-rays from leaking to the outside of the conveyor housing 1 through the conveyor openings 11.

While in any one of the first and second embodiments of the present invention the vacant detectors 4 have been shown and described as positioned above the transport conveyor 2, a plurality of reflective type photoelectric sensors 45 having their optical axes aligned in a direction conforming to the forward and rearward direction FR may be disposed along sides of the shape of a triangle defining the field of coverage A of the X-rays as shown in Fig. 9. Of those photoelectric sensors, the lowermost photoelectric sensors 45 that are closest to the transport conveyor 2 are disposed forwardly or rearwardly of the

transport conveyor 2 so that they can serve as the vacant detectors 4 for detecting the presence or absence of the transport conveyor 2 within the conveyor housing 1. The remaining photoelectric sensors 45 are utilized to assuredly detects the dropout condition of some of the articles M that pass outside the field of coverage A of the X-rays during the transportation of the articles M.

Also, as shown in Fig. 10, as the vacant detectors 4, reflective type photoelectric sensors may be disposed on respective sides of one of apexes of the triangle remotest from and above the transport conveyor 2 in combination with reflecting plates 47 for reflecting respective detecting beams from the photoelectric sensors 4 back towards the photoelectric sensors 4. The reflecting plates 47 are disposed at respective locations corresponding to the remaining apexes of the triangle that define the base thereof so that the detecting beams traveling from the respective photoelectric sensors 4 can travel along the sides of the triangle defining the field of coverage A of the X-rays. Even the arrangement shown in Fig. 10 is effective to assuredly detect the presence or absence of the transport conveyor 2 within the conveyor housing 1 and also the dropout condition of the articles M.

Also, although the display 16 shown in Fig. 1 is in the form of a touch panel display, the display 16 may be of a dedicated type capable of only providing visual presentation of information, in which case one or more operating keys would be necessary. Also, the display 16 may be used to display a radioscopic image of the article M, in which case the use of the display 17 can be dispensed with.

Although in the foregoing embodiments, the conveyor housing 1 has been shown and described as accommodating the single transport conveyor 2, the present invention can be equally applied to the arrangement in which two transport conveyors are disposed in series with each other within the conveyor housing 1.

CLAIMS

1. An X-ray foreign matter detecting apparatus for performing an X-ray inspection of an article by means of X-rays emitted from an X-ray emission source while the article is transported by a transport conveyor, said apparatus comprising:

at least one vacant detector for detecting a non-shielding condition of the apparatus in which at least a portion of the apparatus has been left open and X-rays emitted from the X-ray emission source are not shielded from outside; and

an X-ray emission halting means operable in response to detection of the non-shielding condition of the apparatus to halt emission of the X-rays from the X-ray emission source.

2. The X-ray foreign matter detecting apparatus as claimed in Claim 1, further comprising an electric power switch that is turned off by the X-ray emission halting means, said electric power switch being interposed between the X-ray emission source and an electric power source.

3. An X-ray foreign matter detecting apparatus for performing an X-ray inspection of an article by means of X-rays emitted from an X-ray emission source while the article is transported by a transport conveyor, said apparatus comprising:

a conveyor housing having first and second openings defined therein in opposition to each other with respect to a direction of transport of the article, said transport conveyor being removably accommodated within the conveyor housing with its opposite end portions extending outwardly from the conveyor housing through the first and second openings, respectively;

at least one vacant detector for detecting opening of the first and second openings by detecting removal of the transport conveyor out of the conveyor housing; and

an X-ray shielding shutter provided for each of the first and second openings and operable to close the corresponding opening in response to detection of the opening of the first and second openings.

4. The X-ray foreign matter detecting apparatus as claimed in any one of Claims 1 to 3, wherein the vacant detector is operable to detect absence of the transport conveyor within the apparatus.

5. The X-ray foreign matter detecting apparatus as claimed in Claim 4, wherein the vacant detector is also operable to detect a dropout condition of the article in which at least a portion of the article on the transport conveyor lies out of a field of coverage of the X-ray emission with respect to a widthwise direction of the transport conveyor, and further comprising a warning means for issuing an alarm in response to detection of the dropout condition of the article.

6. The X-ray foreign matter detecting apparatus as claimed in any one of Claims 1 to 5, wherein the vacant detector is also operable to detect change an advance order during change of arrangement.

7. An X-ray foreign matter detecting apparatus for performing an X-ray inspection of an article by means of X-rays emitted from an X-ray emission source while the article is transported by a transport conveyor, said apparatus comprising:

a conveyor housing having first and second openings defined therein in opposition to each other with respect to a direction of transport of the article, said transport conveyor being removably accommodated within the conveyor housing with its opposite end portions extending outwardly from the conveyor housing through the first and second openings, respectively; and

an X-ray shielding shutter provided for each of the first and second openings and mechanically linked with the transport conveyor to close the corresponding opening in response to removal of the transport conveyor out of the conveyor housing.

8. The X-ray foreign matter detecting apparatus as claimed in any one of Claims 1 to 7, further comprising X-ray shielding members disposed on respective sides of an X-ray irradiating position with respect to the direction of transport of the article that is defined on the transport conveyor or below the transport conveyor, said X-ray shielding members being operable to suppress leakage of the X-rays in a direction forwardly and rearwardly with respect to the direction of transport.

9. The X-ray foreign matter detecting apparatus as claimed in any one of Claims 1 to 8, further comprising a drain vat for collecting rinsing water, said drain vat being positioned below the transport conveyor and inclined downwardly with respect to a horizontal level, and a downwardly inclined shielding plate positioned above a scupper defined in the drain vat for discharge of the rinsing water outwardly from the drain vat, for shielding the scupper from the X-rays.

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Application No: GB 0120166.4 **Examiner:** Harvey Dobbs
Claims searched: 1-6, 8 & 9 **Date of search:** 23 April 2002

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.T): G1A (AMZ, AMHR, AMRP)

Int Cl (Ed.7): G01N

Other: Online: EPODOC, WPI, PAJ, TXTE

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	US 4884289	(HEIMANN) Fig. 1 & 2	1,2
Y	US 4530006	(PHILIPS) Fig. 1	1,2
Y	US 4455462	(DE LUCIA) col 4, lines 25 - 24	1,2
Y	US 4027156	(ENERGY RDA) Fig. 2	1,2
X	JP 8178872	(SUTABITSUKU) Fig. & Abstract	1,2

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
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