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(54) Title: RAPIDLY RELOCATABLE MODULAR CARGO CONTAINER SCANNER

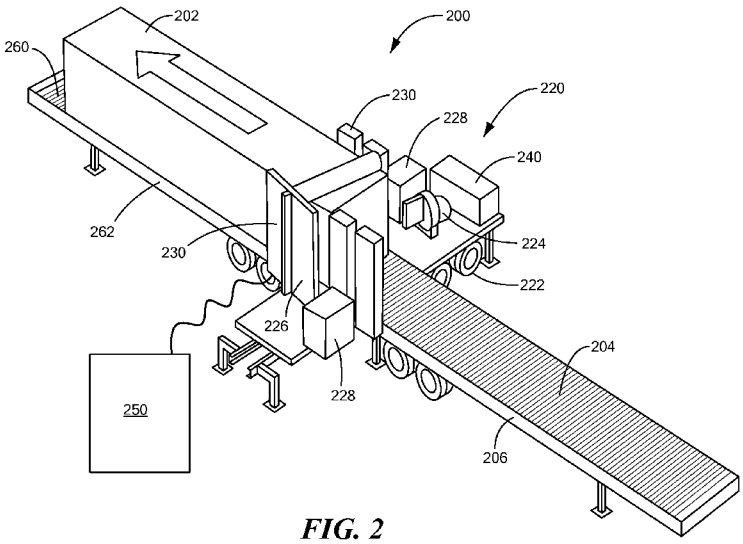

FIG. 2

(57) Abstract: An X-ray cargo inspection system and method. A lead-in conveyor on a first trailer receives a cargo container for inspection. An inspection module disposed on a second trailer then scans the cargo container with penetrating radiation, detects penetrating radiation that has interacted with the cargo container, and produces an inspection signal. An exit conveyor disposed on a third trailer projects the cargo container following scanning. The inspection module may contain transmission or scatter detectors, or both. Multiple lead-in conveyors may serve to load additional cargo containers for subsequent scanning by the inspection module.

Rapidly Relocatable Modular Cargo Container Scanner

[0001] The present application claims the priority of US Provisional Patent Application Serial No. 62/018,787, filed June 30, 2014, which is incorporated herein by reference.

Technical Field

[0002] The present invention relates to systems and methods for inspection of cargo using penetrating radiation, and, more particularly to rapidly relocatable systems and methods for scanning cargo containers.

Background of the Invention

[0003] Cargo containers are frequently subject to inspection at seaports, and screened for contraband goods or articles of terrorism. One common inspection modality uses X-rays, or other penetrating radiation, to traverse the cargo containers and provide images of the contents of the containers. Prior art systems for inspecting cargo containers using X-rays have employed one of two modalities: In one scenario, the cargo containers are borne on a truck or other engine-propelled conveyance and moved relative to a scanning portal (either free-standing or truck-borne) or gantry in order for X-rays to penetrate the entire height of the containers and be detected in transmission. (Relative motion may be achieved either by moving the cargo relative to a fixed portal, or, equivalently, by moving a gantry relative to a fixed object of inspection.) Alternatively, a truck with a gantry may be moved in an inspection path relative to one or more fixed cargo containers.

[0004] An example of a prior art cargo inspection system that is permanently installed is shown in Fig. 1. Cargo containers **10** must be loaded onto a truck **12** and driven through a fixed gantry **14** where X-rays, or other penetrating radiation, derived from a source located in source enclosure **16,** is transmitted through the cargo and detected by detectors (not shown) located within the gantry.

[0005] A deficiency of the prior art permanent inspection installation depicted in Fig. 1 is that cargo containers **10,** to be inspected, must be hauled to a single scanner location. Changes in port layout or flow of commerce may require reinstallation of the entire system which may be very costly and time-consuming.

[0006] It would thus be advantageous to inspect cargo containers without the ponderous set-up overhead entailed in erecting and aligning a cargo scanning gantry, and without requiring that containers be trucked through a portal.

Summary of Embodiments of the Invention

[0007] In accordance with embodiments of the present invention, a cargo inspection system is provided that has a first lead-in conveyor disposed on a first trailer for receiving a cargo container for inspection and an inspection module disposed on a second trailer for scanning the cargo container with penetrating radiation, detecting penetrating radiation scattered by the cargo container and producing an inspection signal. The cargo inspection system also has an exit conveyor disposed on a third trailer for projecting the cargo container following scanning, and a processor adapted for receiving the x-ray inspection signal over a course of passage of the cargo container through the inspection module and for producing therefrom an image characterizing contents of the cargo container.

[0008] In accordance with alternate embodiments of the invention, the inspection module includes an X-ray source, and a transmission detector disposed distal to the cargo container relative to the X-ray source. Alternatively, or additionally, the inspection module includes scatter detector disposed to receive penetrating radiation from the X-ray source that has been scattered by contents of the cargo container.

[0009] In another embodiment of the invention, the cargo inspection system may have one or more additional lead-in conveyors, coupled to the first lead-in conveyor, for loading an additional cargo container for subsequent scanning by the inspection module.

[0010] In accordance with another aspect of the present invention, a method is provided for inspecting cargo disposed in a cargo container. The method has steps of:

a. impelling the cargo container on a lead-in conveyor disposed on a first trailer toward an inspection module;

b. scanning the cargo container with penetrating radiation;

c. detecting the penetration radiation after interaction with contents of the cargo container to generate an detector signal; and

d. receiving the x-ray inspection signal over a course of passage of the cargo container through the inspection module and producing therefrom an image characterizing contents of the cargo container.

[0011] In further embodiments of the present invention, the step of detecting may include detecting penetration radiation that has traversed the cargo container, or penetrating radiation that has been scattered by contents of the cargo container.

Brief Description of the Drawings

[0012] The foregoing features of the invention will be more readily understood by reference to the following detailed description, taken with reference to the accompanying drawings, in which:

[0013] Fig. **1** depicts a typical prior art high-energy transmission X-ray inspection system, in the context of which embodiments of the present invention are advantageously applied.

[0014] Fig. **2** shows a perspective view of a modular cargo container scanning system, in accordance with an embodiment of the present invention.

[0015] Fig. **3** depicts a schematic top view of a multiple modular cargo container scanning systems with multiple conveyor units, employed in tandem in the offloading of a shipping vessel, in accordance with another embodiment of the present invention.

Detailed Description of Embodiments of the Invention

[0016] *Definitions:* As used herein, and in any appended claims, the term "cargo container" refers to any standardized intermodal freight container meeting any set of international dimensional standards, such as ISO standards, for example. It is to be understood that the use of other modes of cargo packaging, such as pallets or skids, similarly falls within the scope of the present invention, and is encompassed by the use, herein, of the term "cargo container."

[0017] A "conveyance" shall be any device characterized by a platform borne on ground-contacting members such as wheels, tracks, treads, skids, etc., used for transporting equipment from one location to another.

[0018] The word "conveyor," as used herein and in any appended claims, shall refer to any handling equipment designed and suited for moving a cargo container from one place to another. A conveyor may employ rollers, driven by chains or otherwise, however other conveyor mechanisms are subsumed within the scope of the present invention.

[0019] The word "trailer," as used herein and in any appended claims, shall refer to a conveyance adapted to be drawn over an underlying surface by a motorized vehicle that may be referred to herein as a "tractor."

[0020] The term "cargo container" shall be used inclusively of its contents.

[0021] The term "X-ray source" shall signify a device that produces X-rays, including, without limitation, X-ray tubes, or Bremsstrahlung targets impinged upon by energetic particles, without regard for the mechanism used for acceleration of the particles, including, without limitation, linacs, etc.

[0022] The systems and methods described herein may be described in terms of X-rays, however the applicability of the teachings to other spectral ranges is clear, and encompasses, within the scope of the invention, all manner of penetrating radiation.

[0023] Methods are well known for inspecting cargo using penetrating radiation (which may be electromagnetic, such as X-rays or gamma rays, or may be comprised of massive particles such as neutrons, etc.). Such radiation emanates from one or more sources and impinges upon an article to be inspected. Similarly well- known methods

are used to pass the penetrating radiation through the entire volume of the inspected article (or, else, specified portions thereof). Passing the penetrating radiation through the inspected volume typically entails scanning, which is to say that the entire volume is not irradiated at once. The penetrating radiation is typically formed into a beam, and the beam profile may have various shapes, such as that of a pencil, or a fan, or a cone. In any event, passing the beam through the inspected volume may be referred to as "scanning." Scanning may entail moving the beam, and/or moving the inspected article. A system for moving cargo relative to an inspecting beam of penetrating radiation may be referred to herein as a "scanning system."

[0024] Inspection of cargo by means of penetrating radiation transmitted through the cargo, at one range of energies, or at multiple ranges of energies, may be practiced with a single beam or with multiple beams, as described in US Published Patent Application Ser. No. US 2013/0136230 (entitled "System and Methods for Multi-Beam Inspection of Cargo in Relative Motion," and incorporated herein by reference). Additionally, cargo may be inspected using detectors disposed for collecting penetrating radiation that is scattered by the inspect article, or by items disposed therein. Inspection of cargo using one or more scatter detection systems (backscatter, for example) is described in US Patent No. 7,400,701 (entitled "Backscatter Inspection Portal," and incorporated herein by reference).

[0025] Referring to Fig. 2, a scanning system, designated generally by numeral **200,** is described in accordance with an embodiment of the present invention. The entirety of the scanning system **200** is assembled for operation from multiple components which are adapted to be coupled to each other using no more than a tractor. A lead-in conveyor **204** serves to impel cargo **202** toward an inspection module **220** and may be any sort of mechanical conveyor suited to convey cargo of the kind being inspected. Lead-in conveyor **204** is disposed on a first trailer **206,** allowing it to be drawn by a tractor (not shown) and positioned as part of scanning system **200.** In different embodiments of the present invention cargo **202** may be conveyed for inspection either in discrete cargo containers, or stacked in any manner, or loaded onto a conveyance for purposes of transport through scanning system **200.**

[0026] Inspection module **220** is disposed on a second trailer **222,** allowing inspection module **220** to be drawn by a tractor (not shown) and positioned as part of scanning system **200.** Inspection module **220** contains either a transmission inspection unit or a backscatter inspection unit, or both. The transmission inspection unit has a source **224** and a transmission detection module **226,** which may include one or more transmission detectors. Source **224** may be referred to herein, for convenience and without loss of generality, as an "X-ray source."

[0027] Each backscatter inspection unit has a source **228** and one or more scatter detectors **230** for detecting penetrating radiation that has been scattered by contents of the cargo container **10.** A beam stop **232** may be provided to reduce or eliminate ambient exposure to penetrating radiation. Electrical power is provided by a generator **240,** allowing for the scanning system **200** to be self-contained and readily moved. While any source **224** of penetrating radiation may be used within the scope of the present invention, a low-output linac or betatron is preferred, in certain embodiments, for their small footprint. Detectors **226** and **230** produce inspection signals which are received by processor **250** over the course of passage of the cargo container **10** through the inspection module **226.** Processor **250** generates images or other diagnostics of the contents of cargo container **10.** Data from scanning system **200** may be conveyed, by cable or wirelessly, to a nearby van, for example, where processor **250** may be housed, as may be an operator or image analyst.

[0028] Cargo container **10,** after scanning at inspection module **226,** is impelled away from the inspection module **220** by an exit conveyor **260** disposed on a third trailer **262.** The three trailers **206, 222,** and **262** may be readily and quickly repositioned by a tractor truck, and the lead-in conveyor **204** and exit conveyor **260** may be readily coupled to inspection module **220** using standard coupling mechanisms.

[0029] In accordance with another embodiment of the present invention, described with reference to Fig. 3, elements of scanning system **200** (shown in Fig. 2) may be multiplexed to increase throughput. Thus, for example, multiple lead-in conveyors **204** may receive cargo containers **10** off-loaded from shipping vessel **300,** and feed them past scanning module **222** for inspection using penetrating radiation.

[0030] A scanning system in accordance with any of the embodiments of the present invention described herein, may advantageously be moved from one location to another in a matter of minutes or hours. Additional advantages accrue from the fact that the containers need not be loaded onto trucks, nor do drivers need to move in and out of their vehicles, or otherwise add time to the scanning operation. Moreover, scanning is more efficient with the present invention, since only the container is scanned, rather than a larger truck.

[0031] Where examples presented herein involve specific combinations of method acts or system elements, it should be understood that those acts and those elements may be combined in other ways to accomplish the same objectives of modular inspection with penetrating radiation. Additionally, single device features may fulfill the requirements of separately recited elements of a claim. The embodiments of the invention described herein are intended to be merely exemplary; variations and modifications will be apparent to those skilled in the art. All such variations and modifications are intended to be within the scope of the present invention as defined in any appended claims.

I claim:

1. A cargo inspection system, the system comprising:

a. a first lead-in conveyor disposed on a first trailer for receiving a cargo container for inspection;

b. an inspection module disposed on a second trailer for scanning the cargo container with penetrating radiation, detecting penetrating radiation that has interacted with the cargo container, and producing an inspection signal;

c. an exit conveyor disposed on a third trailer for projecting the cargo container following scanning; and

d. a processor adapted for receiving the inspection signal over a course of passage of the cargo container through the inspection module and for producing therefrom an image characterizing contents of the cargo container.

2. A cargo inspection system in accordance with claim 1, wherein the inspection module includes an X-ray source.

3. A cargo inspection system in accordance with claim 2, wherein the inspection module includes a transmission detector disposed distal to the cargo container relative to the X-ray source.

4. A cargo inspection system in accordance with claim 2, wherein the inspection module includes a scatter detector disposed to receive penetrating radiation from the X-ray source that has been scattered by contents of the cargo container.

5. A cargo inspection system in accordance with claim 1, further comprising a second lead-in conveyor, coupled to the first lead-in conveyor, for loading an additional cargo container for subsequent scanning by the inspection module.

6. A method for inspecting cargo disposed in a cargo container, the method comprising:

a. impelling the cargo container on a lead-in conveyor disposed on a first trailer toward an inspection module;
b. scanning the cargo container with penetrating radiation;
c. detecting the penetration radiation after interaction with contents of the cargo container to generate an detector signal; and
d. receiving the x-ray inspection signal over a course of passage of the cargo container through the inspection module and producing therefrom an image characterizing contents of the cargo container.

7. A method for inspecting cargo in accordance with claim 6, wherein detecting includes detecting penetration radiation that has traversed the cargo container.

8. A method for inspecting cargo in accordance with claim 7, wherein detecting includes detecting penetration radiation scattered by contents of the cargo container.

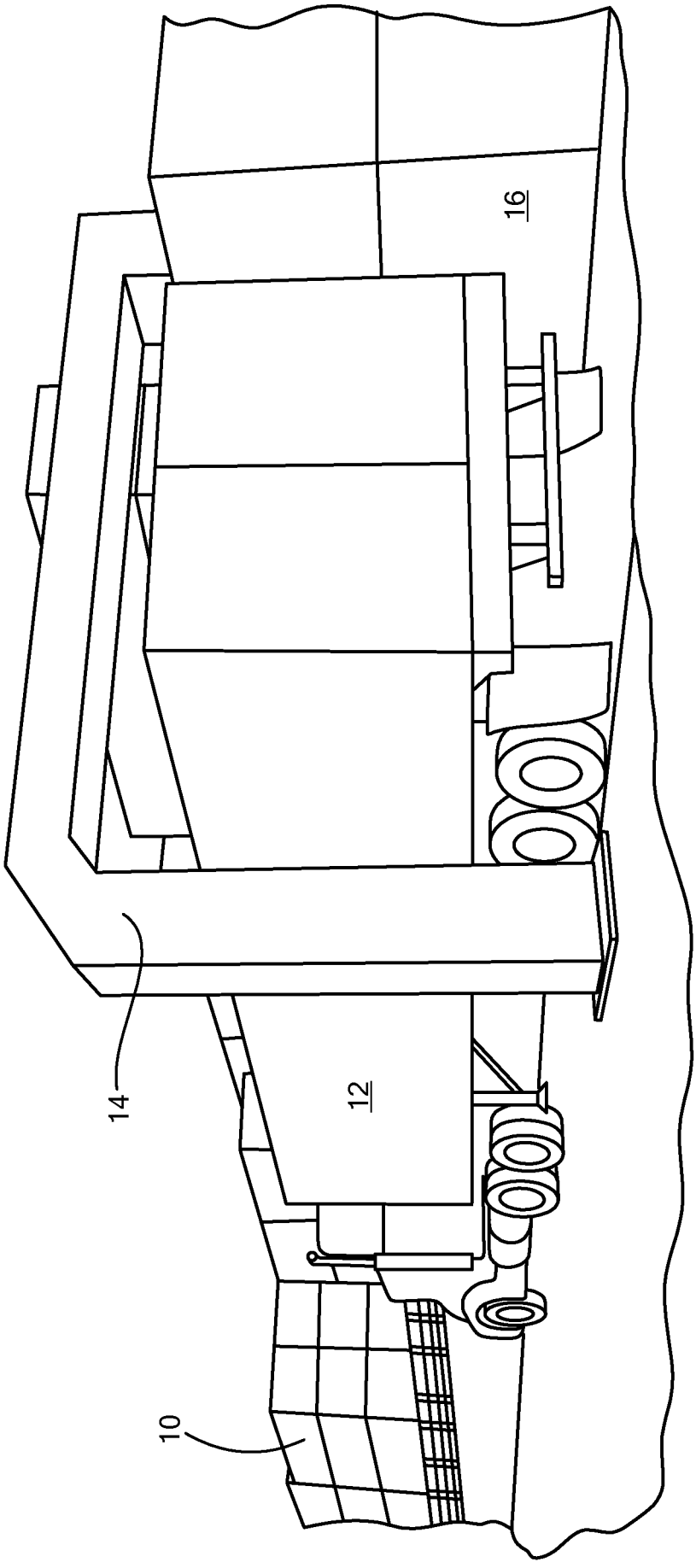

FIG. 1

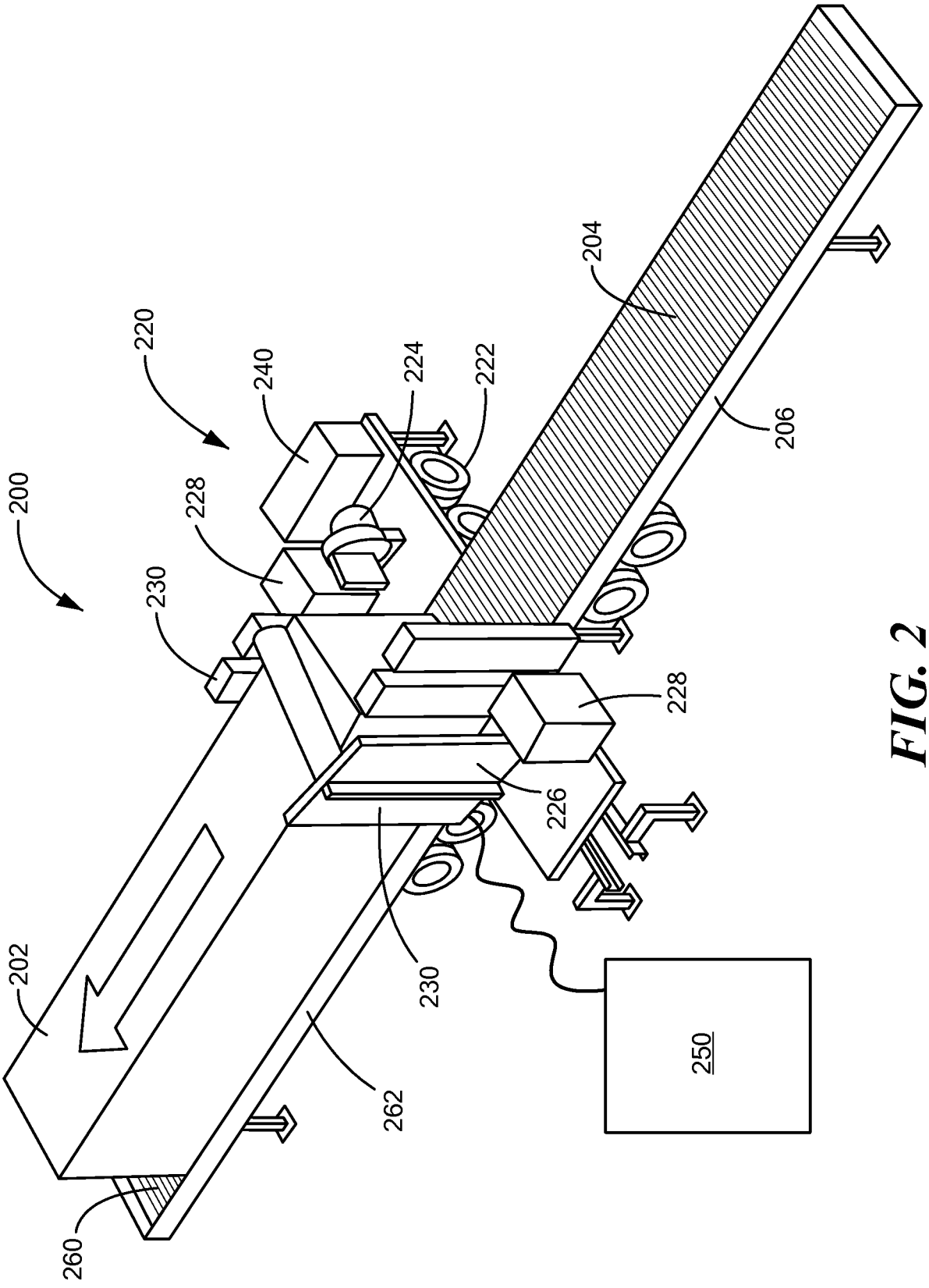

FIG. 2

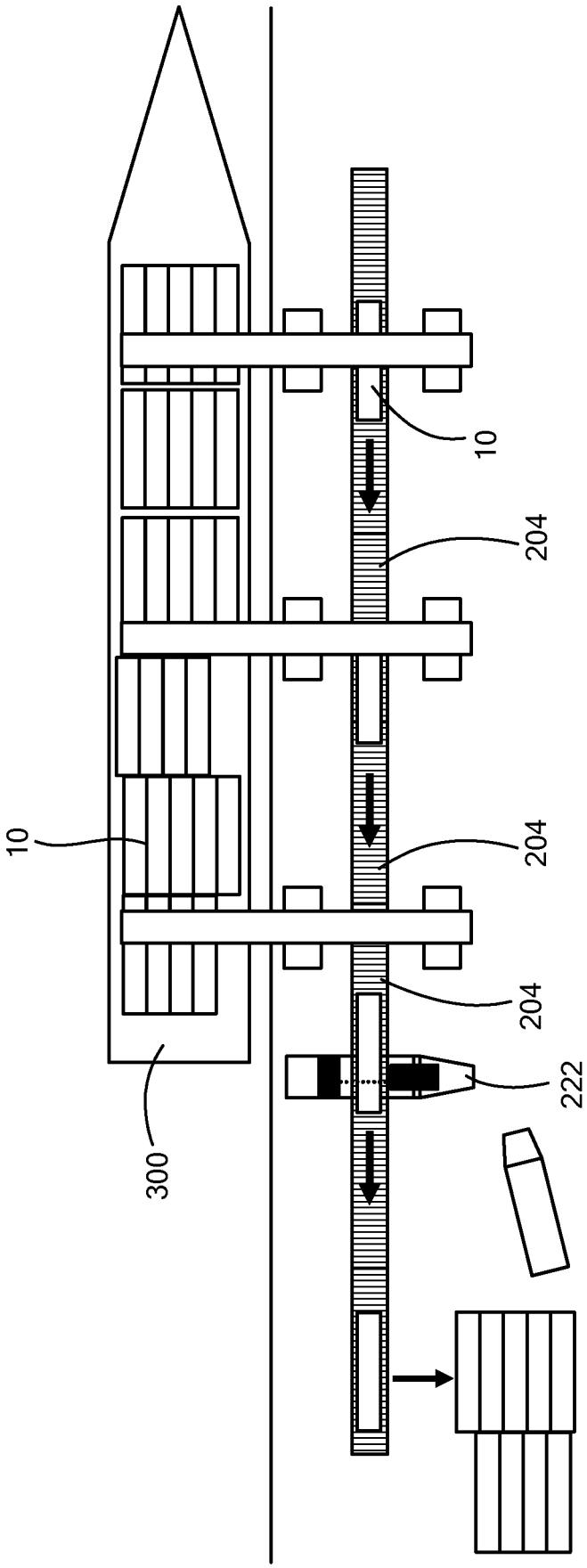

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/031115

A. CLASSIFICATION OF SUBJECT MATTER

G01V 5/00(2006.01)i, G01N 23/02(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01V 5/00; G01N 23/00; G01N 23/04; G01N 23/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: cargo inspection, first lead-in conveyor, exit conveyor, inspection module, trailer, processor, x-ray, radiation, detector, source

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013-0156156 A1 (ROE et al.) 20 June 2013 See abstract, paragraphs [0002], [0023]-[0031], [0036]-[0038], [0062]-[0065], and figures 1, 29.	1-8
Y	US 2008-0197279 A1 (KANG et al.) 21 August 2008 See abstract, paragraphs [0030]-[0037], and figures 1-4.	1-8
A	US 2011-0206179 A1 (BENDAHAN, JOSEPH) 25 August 2011 See abstract, paragraphs [0062]-[0064], and figures 8-9.	1-8
A	US 2013-0039463 A1 (AMERICAN SCIENCE AND ENGINEERING, INC.) 14 February 2013 See abstract, paragraphs [0026]-[0035], and figures 1-2.	1-8
A	US 2012-0076257 A1 (STAR-LACK et al.) 29 March 2012 See abstract, paragraphs [0032]-[0042], and figure 1.	1-8

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/031115

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