MULTI-STAGE SYSTEM FOR VERIFICATION OF CONTAINER CONTENTS

Background of the Invention

1. Field of the Invention

This invention relates in general to shipping container contents detection systems, and more particularly to a noninvasive system and method to detect and identify hazardous materials within containers, such as radiation and/or neutron emitting materials, explosives, and special materials such as highly enriched uranium, and further to identify the normally occurring radiological materials within containers.

2. Description of Related Art

Current attempts at providing radiation, neutron, explosives, and special materials, detection systems to verify shipping containers, such as those that have been mounted on the gantry crane arms, have a limited time to identify the isotopes present. Radiation sensor systems for detecting and identifying radiological materials held within shipping containers may not have the exposure time required to specifically identify all of the isotope types that may be present. The limited time to detect and identify the isotopes present may affect the ability to evaluate the validity of the contents. The limited time provided by current shipping container detection systems, such as for use with gantry cranes, detrimentally affect the commercial viability of radiation, neutron, explosives, and special materials, detection systems and cause the containers to be manually interrogated which results in negative impacts to the flow of commerce.

Therefore a need exists to overcome the problems with the prior art as discussed above.

Summary of the Invention

According to one embodiment of the present invention, a multi-stage detection system and method detects gamma and neutron radiation providing additional data capture times when radiological materials are detected and a secondary position for further analysis. The gamma and neutron detectors mounted on the spreader bar of a gantry crane provide an initial identification of the presence of radiological materials within a shipping container. The spreader bar typically provides up to 30 seconds of close proximity for the radiation sensors to analyze the shipping container. The

radiation data captured is analyzed for specific isotope identification. Should the system require more data to complete the analysis, the spreader bar contact with the shipping container is extended to enable additional data capture. Furthermore, if the shipping container requires further analysis time to determine the specific isotopes present, one embodiment of the present invention provides a secondary radiation analysis position comprised of an array of radiation sensors deployed to allow the targeted container to be further analyzed. The present invention, according to one embodiment, allows an extended time for radiation analysis for those shipping containers where radiological materials have been detected and where the normal flow of the gantry crane movement does not allow for a complete analysis. Additionally, one embodiment of the present invention provides for a secondary radiation analysis position where the additional time for analysis is required beyond that provided at the gantry crane. Another embodiment provides for tracking and monitoring of the targeted shipping container as it moves from the spreader bar to the secondary radiation analysis position.

In order to verify whether radioactive materials are concealed within a shipping container, isotope sensing and identification systems can be deployed in association with a container, such as with a crane assembly used to lift shipping and transfer containers. Typically, the container crane includes a hoist-attachment which engages the shipping container. An isotope sensing and identification system would consist of one or more gamma and neutron detectors that are mounted on the crane hoist-attachment (or on the spreader arm) and provide detailed radiation spectral data to a computer system performing spectral analysis for the detection and identification of isotope(s) that are present in the containers. Many normally occurring radiological materials exist in common goods and cause radiation detection systems to produce false alarms.

The first stage of this process is the detection of the presence of radiological materials within the container. The second stage is to identify the specific isotopes that are present. This second stage may be completed within the 30 second period that is typical for the spreader bar of a gantry crane to be attached to the shipping container as it is moved to and from the vessel. For those instances where additional time is required to collect radiological data for the identification of the isotopes present, the time that the spreader bar is connected to the shipping container may be extended. This could be accomplished in a variety of ways. For example, the spreader

bar movement could be slowed or the spreader bar could remain connected to the container for an extended period of time after being placed into position.

By identifying the specific isotope(s) that are present allows the system to also identify the types of goods or materials that the isotopes represent. With a list of potential goods that represent the identified isotopes, the system can perform a comparison between the identified goods or materials and the shipping container manifest to determine if the radiological material(s) present match the expected materials within the container. The process of 1) identifying the isotope(s) that are within a container, 2) identifying the goods or materials that the isotopes represent and 3) verifying the contents of the manifest against the identified goods, allows the efficient verification of the container without negative impact to the flow of commerce.

According to another embodiment, a neutron pulse device is positioned on the spreader bar to provide active analysis to determine if shielded materials such as highly enriched uranium, explosives, or other materials are present.

According to another embodiment, the radiation sensor system has a secondary position deployed for further analysis of a shipping container where radiological materials have been detected and further analysis is required to determine the specific isotopes that are present. This secondary position along with the spreader bar radiation sensor position are all part of an integrated radiological analysis system. Each radiological analysis system is configured as a node on a multi-node system. The data acquired from the spreader bar sensors is used in conjunction with the data acquired at the secondary position for analysis of the shipping container contents. The shipping container is monitored as it is moved from the spreader bar position to the secondary position. The shipping container may be monitored through the use of CCTV cameras or wireless tracking devices such as radio frequency identification devices.

According to another embodiment, the radiation sensor positions are monitored by a central monitoring station. This central monitoring station may include an interactive graphic display illustrating the map of the port, the placement of the gantry cranes, the placement of the secondary position(s), video cameras and the position of the targeted shipping container as it moves across the port to the secondary position.

According to another embodiment, the radiation sensors for each node on the system are connected to a processor system that collects and analyzes the gamma energy levels and spectral data detected and then sends this data to a spectral analysis engine. Data from each node is individually addressed and sent to the

spectral analysis engine to allow for analysis of individual detector data or detector group data. The analysis engine can combine data from multiple nodes for use in analyzing the shipping container contents.

The processor system and a data collection system are electrically coupled with the sensors of each node to collect signals from the array of neutron sensor devices to form histograms with the collected spectral data. The histograms are used by the spectral analysis system to identify the isotopes that are present.

The spectral analysis system, according to one embodiment, includes an information processing system and software that analyzes the data collected and identifies the isotopes that are present. The spectral analysis software consists of more that one method to provide multi-confirmation of the isotopes identified. Should more than one isotope be present, the system identifies the ratio of each isotope present. Examples of methods that can be used for spectral analysis such as in the spectral analysis software according to one embodiment of a container verification system, include: 1) a Margin Setting method as described in United States Patent No. 6,847,731; and 2) a LINSCAN method (a linear analysis of spectra method) and/or an Advanced Peak Detection method, as described in U.S. Patent Application No. 11/624,121, filed on January 17, 2007, and entitled "Advanced Pattern Recognition Systems for Spectral Analysis", and as will be discussed in more detail below; the collective entire teachings of which being herein incorporated by reference.

A user interface of the information processing system, according to one embodiment, provides a graphic view of the radiation spectra detected and the isotopes identified. The user interface allows a user of the system to view, among other things, the individual detectors, detector groups, individual sensors, and sensor groups, individual nodes and a combination of multiple nodes to quickly identify maintenance conditions, radiation detected, and isotopes identified.

Brief Description of the Drawings

FIG. 1 is a picture depicting a container in proximity to a crane arm assembly (or a spreader bar) with sensors in sensor housings, in accordance with one embodiment of the present invention.

FIG. 2 is a simplified diagram of a secondary radiation verification position.

FIG. 3 is a block diagram illustrating an example of a data collection and analysis system, in accordance with one embodiment of the present invention.

FIG. 4 is a block diagram illustrating an example of a central monitoring system, in accordance with one embodiment of the present invention.

FIG. 5 is a diagram illustrating radiation sensors deployed in a push pull bar configuration of a crane spreader bar, according to one embodiment of the present invention.

FIG. 6 is a diagram illustrating radiation sensors deployed about the main body of a crane spreader bar, according to one embodiment of the present invention.

FIG. 7 is a diagram illustrating multiple background radiation environment effects.

FIG. 8 is a diagram illustrating dynamic background radiation effects compensation.

FIG. 9 is a formula useful for dynamic background radiation effects compensation.

Detailed Description

While the specification concludes with claims defining the features of the invention that are regarded as novel, it is believed that the invention will be better understood from a consideration of the following description in conjunction with the drawing figures, in which like reference numerals are carried forward. It is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one of ordinary skill in the art to variously employ the present invention in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the invention.

The terms "a" or "an", as used herein, are defined as one, or more than one. The term "plurality", as used herein, is defined as two, or more than two. The term "another", as used herein, is defined as at least a second or more. The terms "including" and/or "having", as used herein, are defined as comprising (i.e., open language). The term "coupled", as used herein, is defined as connected, although not necessarily directly, and not necessarily mechanically. The terms "program", "computer program", "software application", and the like as used herein, are defined as a sequence of instructions designed for execution on a computer system. A

program, computer program, or software application may include a subroutine, a function, a procedure, an object method, an object implementation, an executable application, an applet, a servlet, a source code, an object code, a shared library/dynamic load library and/or other sequence of instructions designed for execution on a computer system. A data storage means, as defined herein, includes many different types of computer readable media that allow a computer to read data therefrom and that maintain the data stored for the computer to be able to read the data again. Such data storage means can include, for example, non-volatile memory, such as ROM, Flash memory, battery backed-up RAM, Disk drive memory, CD-ROM, DVD, and other permanent storage media. However, even volatile storage such as RAM, buffers, cache memory, and network circuits are contemplated to serve as such data storage means according to different embodiments of the present invention.

The present invention, according to one embodiment, overcomes problems with the prior art by providing a multi-stage radiation verification process for the contents of a shipping container. The radiation sensor data collected at each stage of the verification process is used to enable detection and identification of the specific isotopes that are present in a container under examination.

A noninvasive container contents detection and verification system, according to one embodiment of the present invention, operates without having to enter the cavity of a container under examination. The system can include multiple radiation sensor systems that use integrated digital sensors for Gamma and neutron detection, and with a spectral analysis capability to identify the specific isotope(s) of materials in containers. The multi-stage system provides for monitoring and tracking of targeted containers that are delivered to a secondary verification station. The multi-stage system provides for network connections between the spreader bar position and the secondary verification position to enable information integration. Such a multi-stage system can also include detection and identification of explosives and special materials in containers. These special materials may include highly enriched uranium.

One embodiment of the invention includes radiation sensors deployed on the spreader bar of a gantry crane to provide radiation detection and isotope identification for the contents of the shipping container. The spreader bar is connected to the shipping container for approximately 30 seconds as the container is moved to or from the vessel at a port. The multi-stage radiation verification system enables radiation

detection and analysis of the contents within the shipping container within the normal 30 seconds while the spreader bar is connected to the shipping container. The multi-stage system also allows for an extended time-period for the spreader bar to stay connected to the shipping container when radiological materials have been detected that the initial 30 second analysis does not allow adequate time for the identification of the isotopes present. In addition, the multi-stage radiation verification system uses a secondary sensor position for continued analysis of the shipping container if additional time is needed beyond the extended time provided at the spreader bar. The shipping container may be tracked as it moves from the spreader bar position to the secondary position. An example of tracking and monitoring devices include CCTV cameras and wireless tracking technologies such as radio frequency identification devices.

According to one embodiment of the present invention, a crane arm assembly mounted sensor system may comprise a node within a distributed network of radiation sensor positions. An example of such a system is described in U.S. Patent Application No. 11/624,089, Filed on January 17, 2007, and entitled "System Integration Module for CBRNE Sensors", the entire teachings of which being incorporated by reference.

According to one embodiment of the present invention, a crane arm (spreader bar) mounted radiation sensor system is used for the detection and first stage of isotope identification for detected radiological material within a shipping container. An example of such a system is described in U.S. patent application 11/363,594 filed on February 27, 2006, and entitled "Container Verification System for Non-Invasive Detection of Contents", the entire teachings of which being incorporated by reference.

A sensor concentrator unit may be used to connect multiple sensors in a group and enable efficient connection to the central processor for spectral analysis. This configuration could utilize a sensor interface unit (SIU) that is comprised of an integrated multi-channel analyzer, high voltage power supply, voltage system and communications interface. This SIU configuration uses a concentrator unit to combine multiple sensors into a concentrated communications channel for connection to the central processor. The communications concentrator provides individual IP addressed for each sensor group. An example of the concentrator unit is a device that provides multiple USB ports for sensor connection and concentrates the USB ports into an Ethernet connection for backhaul.

An embedded processor unit may be used to connect multiple sensors in a group and enable efficient connection to the central processor for spectral analysis. This configuration could utilize a sensor interface unit (SIU) that is comprised of an integrated multi-channel analyzer, high voltage power supply, voltage system and communications interface. This SIU configuration is connected to an embedded processor supporting multiple sensors and providing one or more communications channel(s) for connection to the central processor. The embedded processor provides individual IP addressed for each sensor.

According to another embodiment of the present invention, the time that the spreader bar is connected to the shipping container may be extended to enable further analysis and radiological data acquisition.

According to another embodiment of the present invention, the time that the spreader bar is connected to the shipping container may be extended to enable further analysis and radiological data acquisition.

According to another embodiment of the present invention, a secondary radiation verification system could be deployed as another node of the radiation verification system to enable further analysis and radiological data acquisition.

According to another embodiment of the present invention, the targeted shipping container may be tracked and or monitored as it moves to the secondary radiation verification system.

Described now is an example of a multi-stage radiation detection and identification system with one node mounted on a spreader bar of a crane assembly and another node deployed as a secondary radiation verification position. An example of a process for operation of the system is also discussed.

A radiation detection and identification system deployed on a crane arm (or spreader bar) 102, such as illustrated in FIG. 1, provides the first and second stages of a multi-stage radiation verification system. FIG. 1 illustrates example installation positions for various sensor housings 101, 110. Certain inventive features and advantages of exemplary embodiments of a radiation detection and identification system, such as deployed in connection with a crane assembly or other shipping container handling operation, will be discussed below. However, it is assumed that the reader has an understanding of radiation and sensor technologies.

Referring to FIGs. 1 and 2, an example of a multi-node radiation verification system is shown. The system includes a spreader bar node (as shown in FIG. 1) and

a secondary radiation verification node 202 as shown in FIG. 2. A truck 220 carries a container 222 that contains cargo 215 inside the container 222. Multiple radiation sensors 202 are deployed on either or both sides of the container 222 to enable further analysis of the contents 215. A power distribution station 203 provides power to the sensors. A communication distribution module 204 couple signals between the multiple radiation sensors 202 and a distribution network 210 of which is further described in FIG. 3. Once a container cargo 215 is identified at the spreader bar stage as suspect, the container 222 is tracked and moved from the spreader bar position (as shown in FIG. 1) to the secondary verification position (as shown in FIG. 2) for further analysis. In this example, the secondary verification position includes positioning the container 222 by using a truck to move the container 222 to the multiple radiation sensors 202 deployed on either or both sides of the container 222.

With reference to FIG. 3, a data collection system 310, in this example, is communicatively coupled via cabling, wireless communication link, and/or other communication link 305 with each of the gamma radiation sensor devices 301 and neutron sensor devices 302 in each sensor unit, and with each of the neutron pulse sensor device(s) 303. The data collection system 310 includes an information processing system with data communication interfaces 324 that collect signals from the radiation sensor units 301, 302, and from the neutron pulse device(s) 303. The collected signals, in this example, represent detailed spectral data from each sensor device that has detected radiation.

The data collection system 310 is modular in design and can be used specifically for radiation detection and identification, or for data collection for explosives and special materials detection and identification.

The data collection system 310 is communicatively coupled with a local controller and monitor system 312. The local system 312 comprises an information processing system that includes a computer, memory, storage, and a user interface 314 such a display on a monitor and a keyboard, or other user input/output device. In this example, the local system 312 also includes a multi-channel analyzer 330 and a spectral analyzer 340.

The multi-channel analyzer (MCA) 330 comprises a device composed of many single channel analyzers (SCA). The single channel analyzer interrogates analog signals received from the individual radiation detectors 301, 302, and determines whether the specific energy range of the received signal is equal to the range

identified by the single channel. If the energy received is within the SCA the SCA counter is updated. Over time, the SCA counts are accumulated. At a specific time interval, a multi-channel analyzer 330 includes a number of SCA counts, which result in the creation of a histogram. The histogram represents the spectral image of the radiation that is present. The MCA 330, according to one example, uses analog to digital converters combined with computer memory that is equivalent to thousands of SCAs and counters and is dramatically more powerful and cheaper.

The histogram is used by the spectral analysis system 340 to identify isotopes that are present in materials contained in the container under examination. One of the functions performed by the information processing system 312 is spectral analysis, performed by the spectral analyzer 340, to identify the one or more isotopes, explosives or special materials contained in a container under examination. With respect to radiation detection, the spectral analyzer 340 compares one or more spectral images of the radiation present to known isotopes that are represented by one or more spectral images 350 stored in the isotope database 322. By capturing multiple variations of spectral data for each isotope there are numerous images that can be compared to one or more spectral images of the radiation present. The isotope database 322 holds the one or more spectral images 350 of each isotope to be identified. These multiple spectral images represent various levels of acquisition of spectral radiation data so isotopes can be compared and identified using various amounts of spectral data available from the one or more sensors. Whether there are small amounts (or large amounts) of data acquired from the sensor, the spectral analysis system 340 compares the acquired radiation data from the sensor to one or more spectral images for each isotope to be identified. This significantly enhances the reliability and efficiency of matching acquired spectral image data from the sensor to spectral image data of each possible isotope to be identified. Once the one or more possible isotopes are determined present in the radiation detected by the sensor(s), the information processing system 312 can compare the isotope mix against possible materials, goods, and/or products that may be present in the container under examination. Additionally, a manifest database 315 includes a detailed description of the contents of each container that is to be examined. The manifest 315 can be referred to by the information processing system 312 to determine whether the possible materials, goods, and/or products, contained in the container match the expected authorized materials, goods, and/or products,

described in the manifest for the particular container under examination. This matching process, according to one embodiment of the present invention, is significantly more efficient and reliable than any container contents monitoring process in the past.

The spectral analysis system 340, according to one embodiment, includes an information processing system and software that analyzes the data collected and identifies the isotopes that are present. The spectral analysis software consists of more that one method to provide multi-confirmation of the isotopes identified. Should more than one isotope be present, the system identifies the ratio of each isotope present. Examples of methods that can be used for spectral analysis such as in the spectral analysis software according to one embodiment of a container contents verification system, include: 1) a margin setting method as described in United States Patent No. 6,847,731; and 2) a LINSCAN method (a linear analysis of spectra method) and/or an Advanced Peak Detection method, as described in U.S. Patent Application No. 11/624,121, filed on January 17, 2007, and entitled "Advanced Pattern Recognition Systems for Spectral Analysis"; the collective entire teachings of which being herein incorporated by reference.

With respect to analysis of collected data pertaining to explosives and/or special materials, the spectral analyzer 340 and the information processing system 312 compare identified possible explosives and/or special materials to the manifest 315 by converting the stored manifest data relating to the shipping container under examination to expected explosives and/or radiological materials and then by comparing the identified possible explosives and/or special materials with the expected explosives and/or radiological materials. If the system determines that there is no match to the manifest for the container then the identified possible explosives and/or special materials are unauthorized. The system can then provide information to system supervisory personnel to alert them to the alarm condition and to take appropriate action.

Removal of Background Radiation Effects

Dynamic Background

The background radiation at a seaport and more specifically the changing background associated with a moving container across land, sea, vessels and at

different heights, poses a specific challenge to radiation detection and isotope identification. According to one embodiment of the present invention, this issue is addressed through the use of a dynamic background method used to compensate for the changing background effects. This method applies continuous background updates against the main background data. Different weights and intervals can be varied for the background updates to achieve the appropriate dynamic background for the specific application. An example formula is provided below, and also shown in FIG. 9.

$$Bi(X) = Ai(X) * alpha + Bi\text{-}1(X) * (1\text{-}alpha) \quad (1)$$

Bi (X) =	Ai(X)	* alpha	+ Bi -1 (X)	* (1 - alpha)
New Dynamic Background	Snap Shot of Background	Learning Rate	Previous Background	Differential

As shown in FIG. 7, background radiation effects can vary depending on a varying background environment that can be experienced by the sensors, such as the sensors located at the spreader bar and/or sensors located at locations relative to changing background environments. For example, the sensors at the spreader bar can be over water, over a ship, high over the ground, low over the ground, or inside the ship. These different background environments can affect the radiation detection and isotope identification. Radiation from the sky should typically be predominant and remain normal during spreader bar movement. Also, sensors at the spreader bar should typically be protected by the container under examination and the spreader bar from most of the background radiation coming from the ground, water, and over the ship. Accordingly, a new and novel approach to compensate for the changing background effects applies continuous background updates against the main background data.

As shown in FIG. 8, the dynamic background is comprised of the primary background and the incremental background. As radiation data is collected and processed for analysis, according to one embodiment of the present invention, the background environment effects can be subtracted from the collected data using continuous background updates against a main background data. For example, collected radiation data can be dynamically adjusted according to dynamically

changing background radiation data, such as relating to water, land, air, ground, and other structures. This dynamic background compensation approach has the advantages of increased speed and sensitivity for dynamic background capture, memory efficiency in processing collected data, and flexibility to adjust to variable system parameters and to address specific applications. Further, an information processing system can learn a particular process used in locating sensors during data collection, such as to anticipate the changes in background effects in a normal operation and movement of the spreader bar. Additionally, the dynamic background compensation approach can provide a continuous differential subtraction of the effects of varying background environment. This approach enhances the quality of the analyzed data leading to better and more reliable radiation detection and isotope identification.

According to an alternative embodiment of the present invention, a multiple background analysis approach can be used to remove varying background effects on the collected data. In one example, a GPS detector is mechanically coupled to the structure supporting the moving sensors, such as the crane spreader bar, and provides continuous location data (of the spreader bar) to an information processing system that is processing the collected data. The location of the spreader bar, for example, can indicate the type of background environment that is being experienced by the sensors at the spreader bar. The GPS detector operates in a well known manner and can provide both geographic location information and elevation information. Knowing the elevation of the spreader bar above, say, ground or sea level, can indicate the type of background effects that are experienced by the sensors at the spreader bar. The elevation information, and/or the geographic location information, can be, for example, compared against an expected map of structures and background environments in proximity to the spreader bar. These expected background environments correspond to background effects that can, for example, be subtracted from the collected data to provide better and more reliable data for analysis leading to better and more reliable radiation detection and isotope identification. Alternative location detection devices, including mechanical devices and/or electrical devices and/or manual data entry, can be used by the system to track changing backgrounds and corresponding background effects on collected data.

Another use of the elevation information and the geographic location information by an information processing system is for controlling the triggers and

effects of devices used to collect the radiation data. For example, a neutron pulse may be generated by a neutron pulse device that is included in the sensor system deployed at the spreader bar or on the gantry crane to provide an active analysis whereby gamma feedback following the neutron pulse can identify shielded radiological materials such as highly enriched uranium, explosives or illicit drugs, inside containers. However, a particular system implementation may limit the activation of the neutron pulse device to particular geographic areas and/or elevations above ground and/or sea level. For example, a neutron pulse device can be controlled to remain inactive while the crane and/or spreader bar are in close proximity to a crane operator's cabin or to a protected area such as one normally occupied by people. The flexibility and dynamic adjustment to different operational environments while enhancing the speed and reliability of data analysis, as discussed above, is a significant advantage of the present inventive system that was not available in the past.

The user interface 314 allows service or supervisory personnel to operate the local system 312 and to monitor the status of radiation detection and identification of isotopes and/or the detection of RF signals by the collection of sensor units 301, 302 and 303 deployed on the frame structure, such as on the crane arm assembly (or spreader bar).

The user interface 314, for example, can present to a user a representation of the collected received returning signals, or the identified possible explosives and/or special materials in the shipping container under examination, or any system identified unauthorized explosives and/or special materials contained within the shipping container under examination, or any combination thereof.

The data collection system can also be communicatively coupled with a remote control and monitoring system 318 such as via a network 316. The remote system 318 comprises an information processing system that has a computer, memory, storage, and a user interface 320 such as a display on a monitor and a keyboard, or other user input/output device. The network 316 comprises any number of local area networks and/or wide area networks. It can include wired and/or wireless communication networks. This network communication technology is well known in the art. The user interface 320 allows remotely located service or supervisory personnel to operate the local system 312 and to monitor the status of shipping container verification by the collection of sensor units 301, 302 and 303 deployed on

the frame structure, such as on the crane arm assembly (or spreader bar). The central monitoring system can display the position of the shipping container as it is moved to the secondary position through the use of CCTV cameras (350) or shipping container tracking systems (355).

A neutron pulse device can be included in the sensor system deployed on the spreader bar or on the gantry crane to provide an active analysis whereby gamma feedback identifies shielded radiological materials such as highly enriched uranium, explosives or illicit drugs.

Referring to FIG 4, an example of a multi-node radiation verification system includes multiple spreader bar radiation verification systems (401) and secondary radiation verification nodes (404), operations center (408), container tracking system (410) and CCTV (402) cameras that are interconnected by a data network(405). In some cases a forklift truck is used to move the containers around the terminal. The forklift truck (420) is equipped with a spreader bar and can be configured as a wireless radiation verification node.

Referring to FIG 5, an example of a spreader bar with radiation sensors installed in the push pull bars is shown. In FIG 5, one or more radiation sensors are integrated within the push pull bar 501. The radiation sensors are enclosed in a box with shock absorbing connectors 511. The gamma sensors 512 are shock mounted within the box on the lower side of the unit. The one or more gamma sensors comprise sensor resolution of 7% or better at 662kev. The neutron sensors 514 and the supporting electronics 513 are mounted on the top side of the box. Alternative mounting arrangements of the one or more radiation sensors, the gamma sensors 512, the neutron sensors 514, and the supporting electronics 513, relative to the push pull bar 501 should become obvious to those of ordinary skill in the art in view of the present discussion.

Referring to FIG 6, an example of a spreader bar with radiation sensors installed in the main unit 601 is shown. In the example of FIG 6, the radiation sensors are integrated within the main unit 601. The radiation sensors are enclosed in a box with shock absorbing connectors 611. The gamma sensors 612 are shock mounted within the box on the lower side of the unit. The neutron sensors 613 and the supporting electronics 614 are mounted on the top side of the box. Alternative mounting arrangements of the one or more radiation sensors, the gamma sensors 612, the neutron sensors 613, and the supporting electronics 614, relative to the main

unit 601 should become obvious to those of ordinary skill in the art in view of the present discussion.

By operating the system remotely, such as from a central monitoring location, a larger number of sites can be safely monitored by a limited number of supervisory personnel. Besides monitoring container handling operations such as from crane arm assemblies, as illustrated in the example of FIG. 1, it should be clear that many different applications can be deployed for the initial detection and identification stages for container analysis. For example, fork lift truck mounted sensor units communicating with a remote monitoring system allow radiation detection and identification where large amounts of cargo are moved and handled, such as at ports, railway, and intermodal stations, and at ships, airplanes, trucks, warehouses, and other carrier environments, and at such other places that have large amounts of cargo to handle as should be understood by those of ordinary skill in the art in view of the present discussion.

Additionally, the system monitoring function can be combined to monitor more than radiation and explosives. Other types of hazardous elements can be monitored in combination with the radiation detection by combining appropriate sensors and detectors for these other types of hazardous elements with the radiation sensor units and monitoring system according to alternative embodiments of the present invention.

The preferred embodiments of the present invention can be realized in hardware, software, or a combination of hardware and software. A system according to a preferred embodiment of the present invention can be realized in a centralized fashion in one computer system, or in a distributed fashion where different elements are spread across several interconnected computer systems. Any kind of computer system - or other apparatus adapted for carrying out the methods described herein - is suited. A typical combination of hardware and software could be a general purpose computer system with a computer program that, when being loaded and executed, controls the computer system such that it carries out the methods described herein.

One embodiment according to present invention can also be embedded in a computer program product, which comprises all the features enabling the implementation of the methods described herein, and which - when loaded in a computer system - is able to carry out these methods. Computer program means or computer program in the present context mean any expression, in any language, code or notation, of a set of instructions intended to cause a system having an

information processing capability to perform a particular function either directly or after either or both of the following a) conversion to another language, code or, notation; and b) reproduction in a different material form.

Each computer system may include one or more computers and at least a computer readable medium allowing a computer to read data, instructions, messages or message packets, and other computer readable information from the computer readable medium. The computer readable medium may include non-volatile memory, such as ROM, Flash memory, Disk drive memory, CD-ROM, and other permanent storage. Additionally, a computer readable medium may include, for example, volatile storage such as RAM, buffers, cache memory, and network circuits. Furthermore, the computer readable medium may comprise computer readable information in a transitory state medium such as a network link and/or a network interface, including a wired network or a wireless network that allow a computer to read such computer readable information.

Although specific embodiments of the invention have been disclosed, those having ordinary skill in the art will understand that changes can be made to the specific embodiments without departing from the spirit and scope of the invention. The scope of the invention is not to be restricted, therefore, to the specific embodiments, and it is intended that the appended claims cover any and all such applications, modifications, and embodiments within the scope of the present invention.

What is claimed is:

CLAIMS

1. A multi-stage radiation detection and identification system, comprising:

a radiation sensor system deployed on a gantry crane and comprising:

one or more gamma sensors; and/or

one or more solid-state neutron sensors, wherein the one or more gamma sensors and the one or more solid-state neutron sensors being collectively mounted on a frame structure mechanically coupled to the gantry crane and that can be located in proximity to a shipping container under examination;

a secondary radiation sensor position, that is located separate from the radiation sensor system deployed on the gantry crane, and comprising one or more sensors for analyzing radiological materials detected in the shipping container;

a distributed network communicatively coupling the gantry crane radiation sensor system and the secondary radiation sensor position as individual nodes on a radiation sensor network;

a first digital data collection system, communicatively coupled with the radiation sensors deployed on a gantry crane for collection of radiation data from the radiation sensors on the gantry crane;

a second digital data collection system, communicatively coupled with the radiation sensors deployed at a secondary radiation verification position for collection of radiation data from the radiation sensors at the secondary radiation verification position;

a multi-channel analyzer system, communicatively coupled with the first and second digital data collection systems, for preparing histograms of the collected radiation data;

a spectral analysis system, communicatively coupled with the multi-channel analyzer system and the first and second digital data collection systems, for receiving and analyzing the collected radiation data and the histograms to detect radiation and to identify one or more isotopes associated with the detected radiation using the data acquired from one or more nodes on the network, wherein radiation data collected from the radiation sensors deployed on the gantry crane is used in conjunction with radiation data, if any, collected from radiation sensors deployed at the secondary radiation verification position for analysis of the shipping container contents;

a first data storage means for storing data representing isotope spectra for use

by the spectral analysis system, where one or more spectral images stored in the first data storage unit represent each isotope, the first data storage means being communicatively coupled with the spectral analysis system;

an information processing system, communicatively coupled with the spectral analysis system, for analyzing the identified one or more isotopes and to determine the possible materials or goods that they represent; and

a second data storage means for storing data representing a manifest relating to the container under examination, the second data storage means being communicatively coupled with the information processing system, the information processing system further for comparing the determined possible materials or goods with the manifest relating to the container under examination to determine if there are unauthorized materials or goods contained within the container under examination.

2. The system of claim 1, wherein a first stage of radiation analysis consists of the detection of radiological material within the shipping container from the sensors deployed on a spreader bar of the gantry crane.

3. The system of claim 1, wherein a first stage of radiation analysis consists of the detection of radiological material within the shipping container from sensors deployed on a radiation portal.

4. The system of claim 1, wherein a second stage of radiation analysis consists of the identification of the radiological material within the shipping container from sensors deployed on a spreader bar of the gantry crane.

5. The system of claim 1, wherein a second stage of radiation analysis consists of maintaining sensors deployed on a spreader bar of the gantry crane in close proximity with the shipping container for an extended period of time where additional data is collected from the sensors to further identify the radiological material within the shipping container under examination.

6. The system of claim 1, wherein a second stage of radiation analysis consists of the use of the secondary radiation sensor position where the shipping container is moved to for further analysis.

7. The system of claim 1, wherein a second stage of radiation analysis is performed on the shipping container under examination by sensors deployed on a fork lift truck.

8. The system of claim 1, wherein the one or more gamma sensors comprise integrated analog interface and analog to digital converter.

9. The system of claim 1, wherein the one or more gamma sensors comprise sensor resolution of 7% or better at 662kev.

10. The system of claim 1, wherein the one or more solid state neutron sensors comprise integrated analog interface and analog to digital converter.

11. The system of claim 1, wherein an information processing system being communicatively coupled with the digital data collection system for adjusting collected radiation data to compensate for background radiation effects from the background environment.

12. The system of claim 11, wherein the information processing system dynamically adjusts the collected radiation data according to varying background radiation effects.

13. The system of claim 11, wherein the information processing system adjusts the collected radiation data according to multiple background radiation effects analysis.

14. An explosives, special material and other materials detection and identification system, comprising:

a neutron pulse generator;

one or more radiation sensors to identify gamma or other radiation signals generated from the materials within a shipping container as a result of the neutron pulse;

a data collection system, communicatively coupled to the one or more radiation

sensors, for collecting received returning signals as a result of the neutron pulse;

a spectral analysis and information processing system, communicatively coupled with the data collection system, to analyze the collected received returning signals for detecting materials in the cavity of the shipping container under examination, and to identify the possible explosives and/or special materials therein; and

a data storage means for storing data representing a manifest relating to the shipping container under examination, the data storage means being communicatively coupled with the spectral analysis and information processing system, the spectral analysis and information processing system further for comparing the identified possible explosives and/or special materials with the manifest relating to the shipping container under examination to determine if there are unauthorized explosives and/or special materials contained within the shipping container under examination,

wherein a sensor concentrator is used to connect a group of sensors deployed on at least one frame structure that can be located outside of and in proximity to the shipping container for concentrated communications paths back to a central processor, the sensor concentrator being connected to a sensor interface unit of each sensor; and further comprising

a secondary radiation sensor position, that is located separate from the group of sensors deployed on the at least one frame structure that can be located outside of and in proximity to the shipping container, and comprising one or more sensors for analyzing radiological materials detected in the shipping container, and wherein radiation data collected from radiation sensors deployed on the at least one frame structure is used in conjunction with radiation data, if any, collected from radiation sensors deployed at the secondary radiation sensor position for analysis of the shipping container contents.

15. The system of claim 14, further comprising:

a user interface, communicatively coupled with the spectral analysis and information processing system, to present to a user at least one of

a representation of the collected received returning signals,

the identified possible explosives and/or special materials in the shipping container under examination, and

the system identified unauthorized explosives and/or special materials

contained within the shipping container under examination.

16. The system of claim 14, wherein the special materials include highly enriched uranium.

17. The system of claim 14, wherein the spectral analysis and information processing system compares the identified possible explosives and/or special materials to the manifest by converting the manifest relating to the shipping container under examination to expected explosives and/or radiological materials and then comparing the identified possible explosives and/or special materials with the expected explosives and/or radiological materials.

18. The system of claim 14, wherein a sensor system used for sensing the contents of the container under examination is based on nuclear resonance, gamma imaging, and other advanced technologies for the detection and identification of explosives, radiological material, shielding materials, chemical, and/or biological materials.

19. The system of claim 14, wherein a neutron pulse generator device is implemented as an integrated module within a sensor system to provide active analysis through gamma feedback from substances such as highly enriched uranium, explosives and illicit drugs.

20. The system of claim 14, wherein the neutron pulse generator device is located in proximity to a spreader bar of a gantry crane or a forklift to provide active analysis through gamma feedback from substances inside shipping containers such as highly enriched uranium, explosives, and illicit drugs.

21. The system of claim 14, wherein an embedded processor is used to connect a group of sensors deployed at a spreader bar and supports sensor communications to a central processor, the embedded processor being connected to a sensor interface unit of each sensor.

22. The system of claim 14, wherein an information processing system being communicatively coupled with the digital data collection system for dynamically adjusting collected radiation data to compensate for varying background radiation effects from the background environment.

23. A multi-stage radiation detection and identification system, comprising:

a radiation sensor system deployed on at least one frame structure and comprising:

one or more gamma sensors; and/or

one or more solid-state neutron sensors, wherein the one or more gamma sensors and the one or more solid-state neutron sensors being collectively mounted on the at least one frame structure that can be located outside of and in proximity to a shipping container under examination;

a secondary radiation sensor position, that is located separate from the radiation sensor system deployed on the at least one frame structure, and comprising one or more sensors for analyzing radiological materials detected in the shipping container;

a distributed network communicatively coupling the radiation sensor system and the secondary radiation sensor position as individual nodes on a radiation sensor network;

a first digital data collection system, communicatively coupled with the radiation sensors deployed on the at least one frame structure for collection of radiation data from the radiation sensors deployed on the at least one frame structure;

a second digital data collection system, communicatively coupled with the radiation sensors deployed at the secondary radiation sensor position for collection of radiation data from the radiation sensors at the secondary radiation sensor position;

a multi-channel analyzer system, communicatively coupled with the first and second digital data collection systems, for preparing histograms of the collected radiation data;

a spectral analysis system, communicatively coupled with the multi-channel analyzer system and the first and second digital data collection systems, for receiving and analyzing the collected radiation data and the histograms to detect radiation and to identify one or more isotopes associated with the detected radiation using the data acquired from one or more nodes on the network, wherein radiation data collected

from the radiation sensors deployed on the at least one frame structure is used in conjunction with radiation data, if any, collected from radiation sensors deployed at the secondary radiation sensor position for analysis of the shipping container contents;

a first data storage means for storing data representing isotope spectra for use by the spectral analysis system, where one or more spectral images stored in the first data storage unit represent each isotope, the first data storage means being communicatively coupled with the spectral analysis system;

an information processing system, communicatively coupled with the spectral analysis system, for analyzing the identified one or more isotopes and to determine the possible materials or goods that they represent; and

a second data storage means for storing data representing a manifest relating to the container under examination, the second data storage means being communicatively coupled with the information processing system, the information processing system further for comparing the determined possible materials or goods with the manifest relating to the container under examination to determine if there are unauthorized materials or goods contained within the container under examination.

24. A method for detecting and identifying radioactive materials within one or more containers, the method comprising:

collecting, by a plurality of radiation sensors situated on at least one frame structure located outside of and in proximity to a container, at least one spectral data set representing radiation data associated with the container and its contents, the container being located in proximity to the plurality of radiation sensors;

collecting, by a plurality of radiation sensors located at a secondary sensor position separate from the radiations sensors situated on the at least one frame structure, radiation data from the shipping container, and wherein the radiation data collected from radiation sensors situated on the at least one frame structure is used in conjunction with radiation data, if any, collected from radiation sensors located at the secondary radiation sensor position for analysis of the shipping container contents;

spectrally analyzing the collected at least one spectral data set, in conjunction with radiation data collected from the radiation sensors at the secondary sensor position, associated with the container and its contents;

identifying, based on the spectrally analyzing the collected at least one spectral data set, one or more isotopes associated with the contents within the container;

identifying materials associated with one or more of the identified one or more isotopes;

comparing the materials that have been identified to at least one manifest associated with the container, wherein the at least one manifest lists a set of materials that are declared to be within the container; and

storing a set of comparison results in memory, the set of comparison results being associated with the comparing the materials that have been identified to at least one manifest associated with the container.

25. The method of claim 24, wherein the plurality of radiation sensors include at least one of:

a set of gamma sensors; and

a set of solid-state neutron sensors.

26. The method of claim 24, further comprising:

providing a set of histograms corresponding to the at least one spectral data set, wherein each histogram in the set of histograms represents a different spectral image of radiation associated with the container.

27. The method of claim 26, wherein the identifying one or more isotopes associated with the contents within the container, further comprises:

comparing each histogram in the set of histograms to a plurality of spectral images, wherein each spectral image represents an isotope;

identifying, based on the comparing each histogram, each of the plurality of spectral images that substantially matches at least a portion of a histogram in the set of histograms; and

identifying one or more isotopes associated with the contents within the container, each of the identified isotopes being represented by at least one identified spectral image that substantially matches at least a portion of a histogram in the set of histograms.

28. The method of claim 24, wherein the identifying materials, further comprises:

comparing the identified one or more isotopes to pre-defined one or more isotopes associated with at least one of a plurality of materials, a plurality of goods,

and a plurality of products, that are known to comprise any combination of the pre-defined one or more isotopes; and

identifying, based on the comparing the identified one or more isotopes, at least one material, good, or product, as likely being in the contents of the container, the at least one material, good, or product, comprising one or more of the identified one or more isotopes.

29. The method of claim 24, wherein the spectrally analyzing further comprises:

spectrally analyzing radiation data in the collected at least one spectral data set over a frequency range and an associated collected neutron count, wherein in the analyzing of the radiation data a collected non-zero neutron count corresponds to subtracting radiation data corresponding to the collected non-zero neutron count from the radiation data in the collected at least one spectral data set.

30. The method of claim 24, wherein the identifying one or more isotopes associated with the contents within the container further comprises:

spectrally analyzing a spectral image in a histogram representing a composite spectral image associated with the container and the contents within the container;

comparing a plurality of spectral images to at least a portion of the spectral image in the histogram, wherein each spectral image in the plurality of spectral images represents an isotope;

identifying, based on the comparing, a first spectral image from the plurality of spectral images that substantially matches at least a portion of the spectral image in the histogram;

subtracting the identified first spectral image from the spectral image in the histogram resulting in a remaining spectral image in the histogram; and

repeating the comparing, identifying, and subtracting, for each subsequent spectral image in the plurality of spectral images, wherein each subsequent spectral image after being identified in at least a portion of the remaining spectral image in the histogram, is then subtracted from the remaining spectral image in the histogram.

31. The method of claim 24, further comprising:

before the spectrally analyzing the collected at least one spectral data set, subtracting one of a plurality of dynamically changing background radiation data from the collected at least one spectral data set.

32. A method for dynamically adjusting spectral data collected from one or more containers for detecting and identifying radioactive materials therein, the method comprising:

providing a plurality of dynamically changing background radiation data corresponding to different background environments about the container;

collecting, by the plurality of radiation sensors, at least one spectral data set representing radiation data associated with the container and its contents, the container being located in proximity to the plurality of radiation sensors; and

dynamically adjusting the collected at least one spectral data set according to one of the plurality of dynamically changing background radiation data.

33. The method of claim 32, wherein the dynamically adjusting further comprises:

selecting one of the plurality of dynamically changing background radiation data; and

subtracting the selected one of the plurality of dynamically changing background radiation data from the collected at least one spectral data set.

34. The method of claim 32, further comprising:

spectrally analyzing the collected at least one spectral data set that has been dynamically adjusted;

identifying, based on the spectrally analyzing the collected at least one spectral data set that has been dynamically adjusted, one or more isotopes associated with the contents within the container;

identifying materials associated with one or more of the identified one or more isotopes;

comparing the materials that have been identified to at least one manifest associated with the container, wherein the at least one manifest lists a set of materials that are declared to be within the container; and

storing a set of comparison results in memory, the set of comparison results being associated with the comparing the materials that have been identified to at least one manifest associated with the container.

35. The method of claim 32, wherein the different background environments comprise at least one of:

water;

land;

air;

ground; and

other containers.

36. A system for detecting and identifying radioactive materials within one or more containers, the system comprising at least:

a plurality of radiation sensors situated on at least one frame structure located outside of and in proximity to a container, wherein the plurality of radiation sensors are adapted to collect at least one spectral data set representing radiation data associated with the container and its contents, the container being located in proximity to the plurality of radiation sensors;

a secondary radiation sensor position, that is located separate from the plurality of radiation sensors situated on the at least one frame structure, and comprising one or more sensors for collecting radiation data from the shipping container;

an information processing system communicatively coupled to the plurality of sensors, wherein the information processing system is adapted to:

spectrally analyze the collected at least one spectral data set in conjunction with radiation data, if any, collected from radiation sensors deployed at the secondary radiation sensor position, associated with the container and its contents;

identify, based on the spectrally analyzing the collected at least one spectral data set and radiation data, one or more isotopes associated with the contents within the container;

identify materials associated with one or more of the identified one or more isotopes;

compare the materials that have been identified to at least one manifest associated with the container, wherein the at least one manifest lists a set of materials that are declared to be within the container; and

store a set of comparison results in memory, the set of comparison results being associated with the comparing the materials that have been identified to at least one manifest associated with the container.

37. The system of claim 36, wherein the information processing system is further adapted to:

provide a set of histograms corresponding to the at least one spectral data set, wherein each histogram in the set of histogram represents a different spectral image of radiation associated with the container.

38. The system of claim 37, wherein the information processing system is further adapted to identify one or more isotopes associated with the contents within the container by:

comparing each histogram in the set of histograms to a plurality of spectral images, wherein each spectral image represents an isotope;

identifying, based on the comparing each histogram, each of the plurality of spectral images that substantially matches at least a portion of a histogram in the set of histograms; and

identifying one or more isotopes associated with the contents within the container, each of the identified isotopes being represented by at least one identified spectral image that substantially matches at least a portion of a histogram in the set of histograms.

39. The system of claim 36, wherein the information processing system is further adapted to identify materials associated with one or more of the identified one or more isotopes by:

comparing the identified one or more isotopes to pre-defined one or more isotopes associated with at least one of a plurality of materials, a plurality of goods, and a plurality of products, that are known to comprise any combination of the pre-defined one or more isotopes; and

identifying, based on the comparing the identified one or more isotopes, at least one material, good, or product, as likely being in the contents of the container, the at least one material, good, or product, comprising one or more of the identified one or more isotopes.