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PRELIMINARY STUDY ON THE GAMMA-RAY CARGO SCANNER DESIGN FOR INDONESIAN PORTS

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ABSTRAK

STUDI AWAL DESAIN KARGO SCANNER SINAR GAMMA UNTUK PELABUHAN LAUT INDONESIA. *Pemindaian kargo telah menjadi metode populer untuk mencegah masuknya barang-barang terlarang ke negara tertentu. Sistem inspeksi secara manual akan memakan waktu dan biaya; Oleh karena itu, pemeriksaan yang tidak memerlukan bongkar muat barang sangat diiperlukan. Penggunaan x-ray telah menggantikan sistem manual di banyak tempat, namun karena sifat penetrasi dari sinar tersebut, tidak dapat menggambarkan isi kargo secara akurat. Penggunaan sinar gamma akan dapat meningkatkan resolusi gambar yang dihasilkan, sehingga memverifikasi isi kargo seperti yang tercantum dalam dokumen manifest. Indonesia yang memiliki sekitar 636 pelabuhan sangat membutuhkan sistem tersebut, karena penyelundupan barang dan perdagangan manusia yang sangat sering terjadi di negara ini. Beberapa sistem pemindaian kargo sinar gamma telah dipasang di beberapa pelabuhan di Indonesia, namun masih diimpor dan mahal harganya. Badan Tenaga Nuklir Indonesia (BATAN) berinisiatif untuk memulai pengembangan sistem tersebut dengan peningkatan kandungan lokal mulai dari desain hingga pembuatannya. Studi ini akan mempelajari sistem yang telah ada dan mencoba mengusulkan beberapa kebutuhan pengguna untuk sistem tersebut agar dapat dikembangkan oleh BATAN. Penggunaan bahan lokal harus menjadi salah satu hal penting di dalam desain, untuk menekan biaya pembuatan alat.*

Kata kunci: Sinar Gamma, kargo scanner, keamanan.

ABSTRACT

PRELIMINARY STUDY ON GAMMA-RAY CARGO SCANNER DESIGN FOR INDONESIAN PORTS. *Cargo scanning has become a popular method of preventing illicit goods from entering a particular country. The manual inspection system would consume time and cost; therefore, a non-intrusive inspection is desirable. The use of x-ray has replaced the manual system in many places, however, due to its nature of penetration, it cannot describe the content of the cargo precisely. The use of gamma-ray would increase the resolution image produces, hence verifying the content of the cargo as stated in the documents. Indonesia which has about 636 seaports has a high need for such system since smuggling of goods and human trafficking is very common in the country. Few existing gamma-ray cargo scanning systems have been installed in several ports in Indonesia, however, it is still imported and costs a fortune. The Nuclear Energy Agency of Indonesia initiates the development of such system with the increase of local content starting from its design until the manufacturing. This study will show the existing system and try to propose some mechanical and electrical user requirements for the system. The use of local content should become the primary consideration in the design to reduce the cost of the development.*

Keywords: Gamma Ray, Cargo Inspection, Security.

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1. INTRODUCTION

There is a growing worldwide need for efficient cargo containers' scanning in order to detect possible contraband or illegal goods, such as weapons, explosives, drugs, smuggled goods and even human trafficking through the imaging of large objects, such as cargo containers, unoccupied vehicles, trains, trucks or boats. The manual inspection of large containers, by unpacking and repacking the cargo, is not practical because of the time constrains and the high labour requirements. A more practical way is required to perform such scanning such as the use of X-ray to observe the object inside the container. These systems have gained popularity over the past decade and their use has expanded rapidly in recent years. X-ray based inspection systems are the most common form of non-invasive inspection technology[1]. It can detect differences in material densities in order to produce an image of the cargo content. The images obtained from the scan are visually inspected by the human operator in order to detect anomalies in the cargo content, together with the use of dedicated software. However, the electrons produced by X-ray cannot penetrate deep to the inside of the cargo container[2]. Also, due to the nature of X-rays methods, specific materials cannot be detected. Therefore, the use of more advanced technologies such as gamma-rays is needed in order to detect specific materials like drugs and explosives[1].

One other technique used to search for nuclear weapons and other radioactive materials in containers is such as Radiation Portal Monitor[3 – 7]. In this system which is considered as a passive γ-ray or neutron detection system, a large-area, high-efficiency detectors were utilized which can detect threat levels of radioactivity at practical traffic speeds. However, in the case the radioactive source is heavily shielded by dense, high-Z material, this technique may fail to detect the source. In this case, a complementary technique, such as X-ray or γ ray radiography can help by detecting the dense material[7].

Gamma ray is known to have the highest penetration capability to such an extent even paper and plastic inside the cargo can be differentiated. This way of scanning has so far produced many satisfactory images to prevent the smuggling of unwanted goods. This radiographic imaging can also help verify that the container contents are consistent with the manifest. It also means solving the problem of false alarm produced by naturally radioactive material commonly found in cargo (such as ceramic tiles, porcelain toilet bowls or cat litter)[7]. Since this system can also provide high-resolution intensity images, it is well suited for detecting metal-based objects such as weapons. By the help of other software and/or the operator, the images obtained from the systems are easy to interpret due to the high contrast shapes[7]. It can also produce an intensity image or 3D mapping of the cargo content. Few of the detectable substances are carbon, nitrogen, silicon, oxygen. chorine, iron or aluminium[1].

In terms of scanning time, the average inspection throughput of gamma-ray systems is 10 times greater than the fastest X-ray system or even more. It can also be produced also as mobile or fixed-site units which cost 3-20 times less than the X-ray systems in terms of initial capital investment[1].

In Indonesia, this gamma-ray inspection system is not so popular. However, there are few ports in Indonesia, which has installed such system. However, so far these devices were quite expensive and need to be imported from outside the country. The Nuclear Facility Engineering Centre of the Nuclear Energy Agency of Indonesia, has initiated to start the development of such cargo scanning inspection to be installed in Indonesian ports or other designated places. This study is to find out the current development of such scanner and set the user requirement of such system which includes increasing the use of local content during the development of the system.

2. THEORY

A gamma ray or gamma radiation (symbol γ), was discovered by Paul Villard a French chemist and physicist in 1900. It is a penetrating form of electromagnetic radiation arising from the radioactive decay of atomic nuclei. It has the shortest wavelength electromagnetic waves, hence imparts the highest photon energy. Based on its penetrating power, Ernest Rutherford in 1903 named this radiation as *gamma rays* based on their relatively strong penetration of matter. Previously there were two less penetrating types of decay radiation (discovered by Henri Becquerel), named alpha rays and beta rays (in ascending order of penetrating power) .

The energy range of Gamma rays produced from radioactive decay are between a few Kilo Electron Volts (keV) to approximately 8 Mega Electron Volts (~8 MeV), corresponding to the typical energy levels in nuclei with reasonably long lifetimes. The energy spectrum of gamma rays can be used to identify the decaying radionuclides using gamma spectroscopy. There are even higher energy gamma rays, classified in a Very-high-energy in the 100–1000 Tera Electron Volt (TeV) range, which have been observed from sources such as the Cygnus X-3 microquasar[9].

Gamma rays are produced naturally originating on Earth, mostly as a result of radioactive decay and secondary radiation from atmospheric interactions with cosmic ray particles. However, there are other rare natural sources, such as terrestrial gamma-ray flashes, which produce gamma rays from electron action upon the nucleus. There are also such artificial sources of gamma rays which include fission, which usually occurs in nuclear reactors, and high energy physics experiments, such as nuclear fusion.

To differentiate between Gamma rays and X-rays, they are distinguished by their origin: Gamma rays are created by nuclear decay, while in the case of X-rays, the origin is outside the nucleus. They both are electromagnetic radiation, and since they overlap in the electromagnetic spectrum, the terminology varies between scientific disciplines. Other definition of gamma rays is set in astrophysics; gamma rays are conventionally defined as having photon energies above 100 keV and are the subject of gamma ray astronomy, while radiation below 100 keV is classified as X-rays and is the subject of X-ray astronomy. It initiates from the early man-made X-rays, which had energies only up to 100 keV, whereas many gamma rays could go to higher energies.

Since gamma rays are ionizing radiation, thus it biologically hazardous which can damage bone marrow and internal organs. A shielding made from lead or concrete, is required to protect the body from a great danger. Gamma rays cannot be reflected off a mirror and their wavelengths are so small that they will pass between atoms in a detector[1].

Radioactive sources are very dangerous which require specialized shipping containers and services with heavy shielding and high levels of security. The radioactive sources once delivered, need to be placed in a specialized room with good shielding. The personnel handling it must also have background checks, as well as radiation badges to deal with the radioactive source. This unstable material is constantly decaying and cannot be turned off. For example, Cobalt-60's half-life is 5.27 years while cesium-137's half-life is 30.17 years. Once the radiation source activity is below the minimum level, generally it cannot be reloaded and must be disposed of with some specific protocols, which is costly and involve shipping containers and long-term storage, in the case of the radioactive source which has a lifetime to hundreds of years[10].

X-ray ionizing radiation, on the other hand, is produced by an X-ray tube, therefore it can be turned on and off. At 160 kV, for example, an X-ray has more than enough penetration power to achieve the desired results and at the same time requires much less shielding. In some country, it does not even require any special licensing or special room accommodations[11]. Moreover, the operator also does not require background checks prior to operation nor do they require the use of radiation badges. When the X-ray unit reaches the end of its lifecycle, the disposal cost is quite low[10].

3. RECENT WORKS

There were some existing gamma-ray scanning systems which have been developed. Orphan of Science Application International Corporation (SAIC), USA, has proposed a gamma-ray scanning system called developed the Integrated Container Inspection System (ICIS), an open-architecture system that uses γ ray imaging, passive radiation scanning and optical character recognition (OCR) identification to scan containers in normal terminal traffic[7]. The arrangement of gamma ray source and detector can be seen in Figure 1.

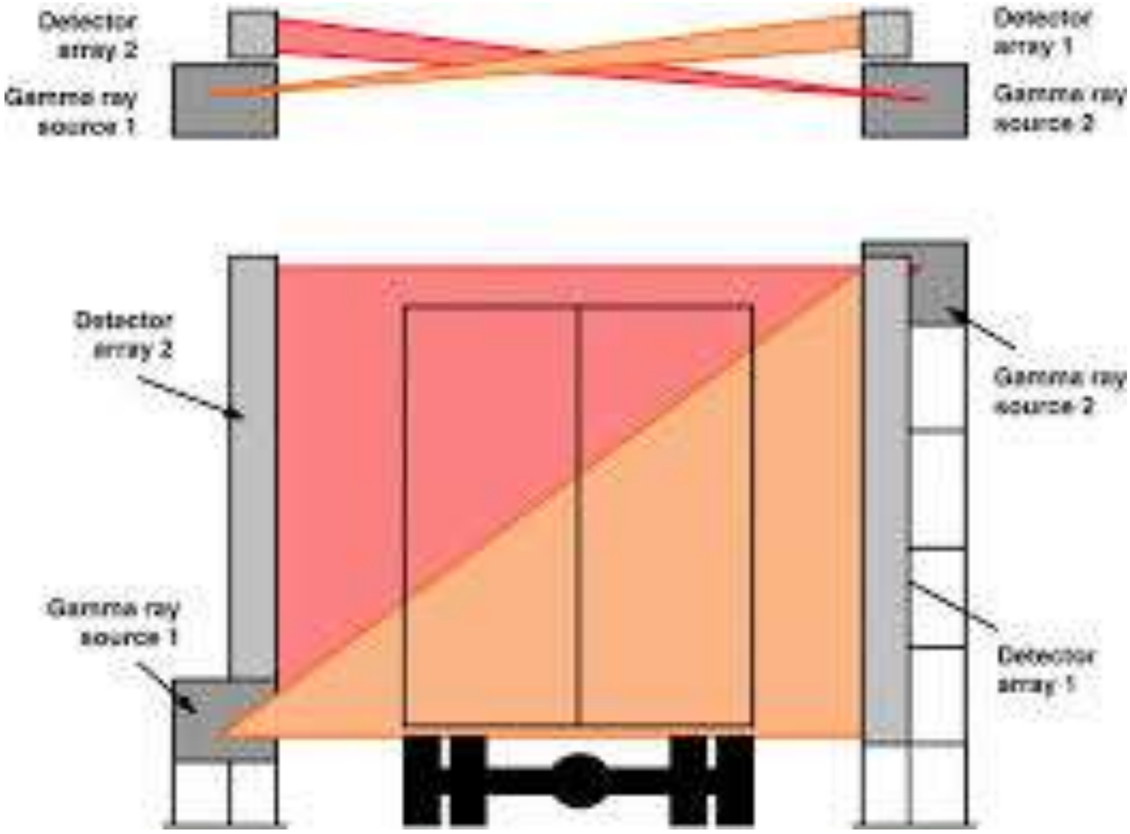

Figure 1. The configuration of Gamma Ray source and Detector for ICIS system**[7]**.

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The principle of the system can be seen in Figure 2.

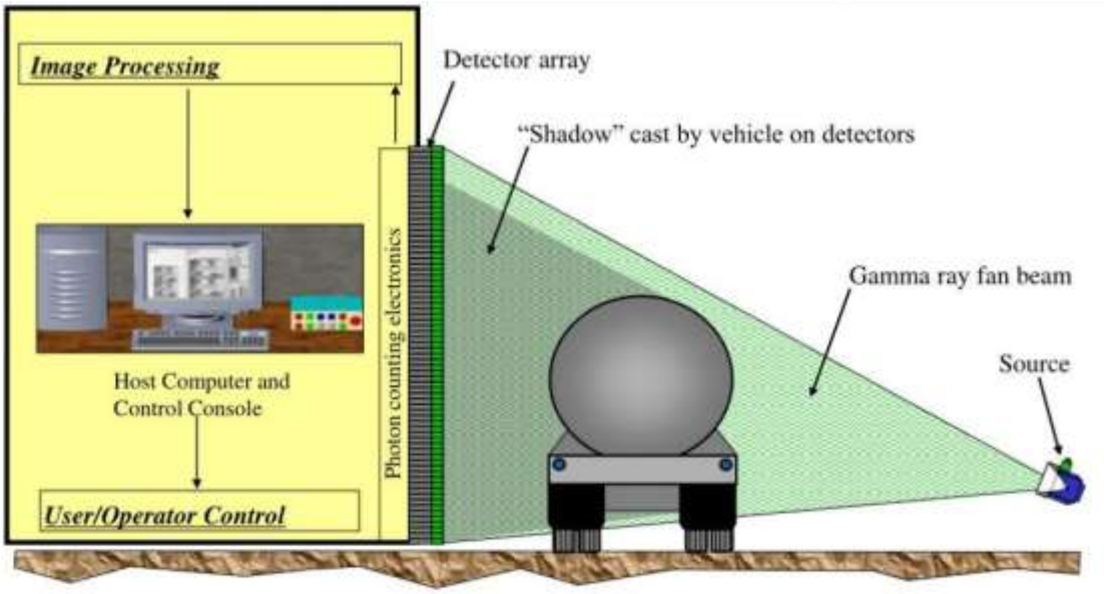

Figure 2. Principle of VACIS system [12].

The resulting image ofthe VACIS gamma-ray scanning is as follow

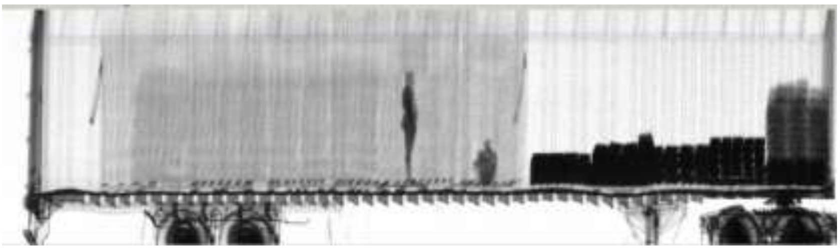

Figure 1. Resulting Image of VACIS Scanning[13].

The above system has also been installed in Indonesia such as in Tanjung Perak Port as can be seen in Figure 4. There are two types of models installed, one is the stationary type and other is the mobile type (Figure 4 left and right).

Figure 2. VACIS Gamma Ray Scanner installed in Tanjung Perak, Surabaya Indonesia[14].

There also another non-intrusive inspection system based on gamma-ray imaging called ROBOSCAN 1M developed by MBTechnology of Hungaria as can be seen in Figure 5. In terms of safety, the system provides a smaller operational area and exclusion safety zone, since it has a lower radiation field compared to existing X-ray systems, It requires also less maintenance at a lower cost. It is also able to scan containers, vehicles, rail cars, while automatically detecting radioactive materials[1].

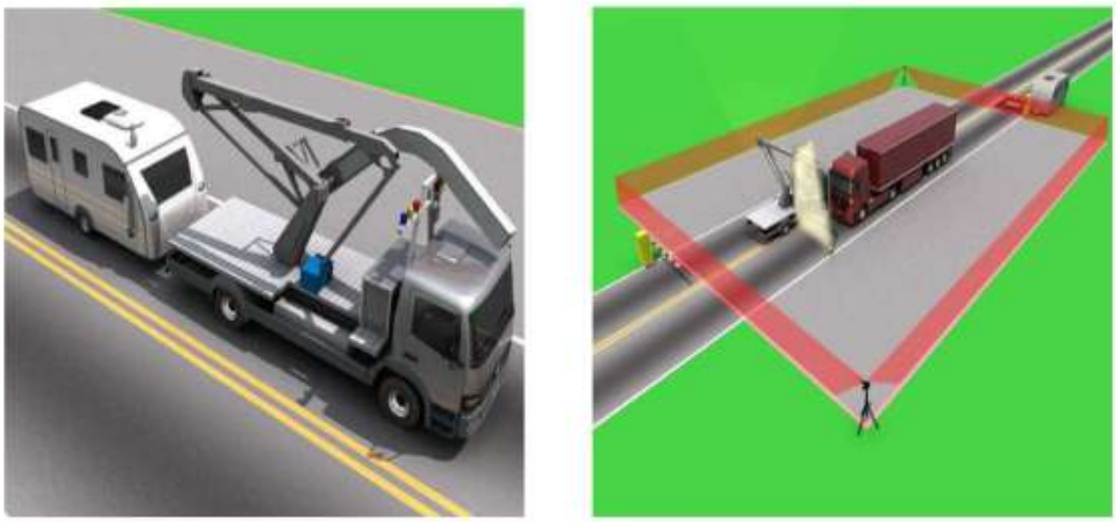

Figure 5. ROBOSCAN 1M system.

Safety Issue

In these designs, the second design has considered the safety issue more carefully, since the driver need to get out from the vehicle before the scanning. However, this might consume time and therefore not time efficient. Recent study has shown that the preliminary results of Monte Carlo simulations concerning the dose of drivers during scanning operations, including the dose due to a failure of safety system, producing an exposure of drivers to the direct beam, as well as, an analysis of the justification of practice, mainly related to the drive-through operational procedure[2].

4. RESULT AND DISCUSSION

This study come up with some requirement for such system. First of all, there should be a scan area, where the truck or cargo will be examined. It might consist of traffic lights, scanning lanes, and other equipment needed to make a scan. Scanning lanes are places where scanning operations are performed, and where traffic is controlled. Each portal should have 1 scanning lane. The controller enters the scanning lane to start the scanning operation. While the Traffic light should be located near the scanning lane. Normally, there should be 3 different traffic lights such as entry, scan, and exit placed in different positions. Each of these equipment has a red and green light, which is done by the controller to stop or go forward. The number of Traffic lights varies depending on the place, but the Entry Traffic light is always there. In the scan area, there should be something called Light Curtain or a collection of sensors that are placed vertically. Light Curtains are placed adjacent to the Detector Towers at each corner of the Scanning lanes. The Light Curtain detects the presence of vehicles and ensures there is separation between cab and trailer. This allows the driver to avoid Gamma Ray before the shutter is opened and the scan begins. It also detects the end of the vehicle which will automatically stop scanning. A speaker is required to communicate between the operator in the control booth and the driver. A sensor, either a radar gun or VLD sensor should be installed to get the optimum speed of the vehicle, in order to produce accurate scan results. A zoom and tilt camera should be placed in a strategic place in front of the scanning lanes to identify the vehicle. The image produced by the camera should be stored and permanently attached to the vehicle scan results. If required, several cameras can be installed.

The second part is the detection system. A pair of detector tower, which can cover the height of normal container or cargo should be used. These detectors will measure the amount of radiation hitting it from the corner opposite the source. A specific requirement for the application in the seaport, the tower should be designed such that it will withstand winds and low-level seismic activity. These detectors will then be connected to the processing device. On the opposite side, a source enclosure - a steel cabinet as part of the source holder security system and protects against natural elements. This device should have radiation protection shielding in the top, bottom, two sides and the back.

The third part is the power system. It usually consists of Circuit Breaker Panel, Main Power Switch, System UPS or Solar System as a back-up power in the event of a power failure. The UPS system must always be on and supported by the Circuit Braker Panel or Main Power Switch. The other important part is the Computer System. It might consist of Computer Monitor (touch screen preferable), Keyboards, Microphone, mouse, printers and internet connection. The audio system that allows the operator to enter his comments into the display file (image). Operators can record words or comments into an image file.

The last part of the system is the Operator Control Panel. It will operate switches, buttons, and indicator lights to control and monitor the Operator-Initiated Inspection System. Operators run on and off scans from the Operator Control Panel. This will control the opening and closing of the source shutter as well as different indicators and/or lights of the state of the source, for safety reason. An Emergency Stop Button (E-STOP) would be desired to close the source Shutter in an emergency. Some other indicator might be required for traffic status such as Entry, Scan or Exit status. When the driver is ready, the operator would have to press a Scan Button to start the scanning process. A separate Exit Button is required, to indicate the process is over, and status back to Entry.

The most important part, in terms of safety, is the Internal source such as: source, source Holder, Collimator, and Shutter. Source Holder: is a place for radioactive isotopes and the source Primary Shutter mechanism. This holder contains a tungsten shield to reduce radiation levels from the source. The source holder is positioned so that the gamma rays hit the detectors. Inside this holder is the source, a small isotope like aspirin, for example Cobalt 60 radioactive source. Above the front of the source holder, there would be a Collimator to reduce beam width and height less than a certain degree. Other than this, there will two types of shutters. First is the Secondary Shutter which is placed directly in front of the source Holder, a cylinder with a rotating slit that allows gamma rays to be emitted. While the other shutter is the Primary Shutter placed inside the source Holder. This component is a cylinder with a rotating slit that allows the gamma ray to escape from the source Holder. The Primary Shutter opens when the System Key Switch on the Operator Panel is turned to ENABLE.

Safety Issue

If the system is equipped with a Primary Shutter and a Secondary Shutter, the Primary Shutter will remain open while the system is operating. This is the safety feature of the source, in which only when both shutters open then a beam of radiation enters surrounding environment. There is another safety feature for the source such as warning indicators lamp when the shutter is opened, as well as emergency stop button explained above. The source Shutter should be closed automatically under the following circumstances:

- If the power is off, the Primary and Secondary Shutter will close.
- If an error occurs for more than 2 minutes without operator intervention, Secondary Shutter will close.

The system should be placed in such a way that it should protect the operator and people around the scanning area from accidental exposure to gamma rays.

The source Holder would contain a radioactive source made of cast iron and reinforced (lined) with tungsten and steel. Tungsten is a heavy metal, used to prevent radiation leakage. The back of the Detector Tower is steel lined and filled with steel shot to protect and reduce radiation range. The source enclosure is equipped with lead on all sides except the front.

Future work

Development of detector for gamma rays will support the image enhancement of the system[15][16]. Such detector will solve the problem of limited Field of View (FOV). Hence, image produced from different angle from the cargo scanning can forme a better 3D image. Such system of Radiological Multi-sensor Acquisition Platform (RADMAP)[17][18] can become a design concept, in which few detectors, cameras and modalities were combined, in order to produce more data quantitatively and qualitatively. The use of Compton camera, can also a better view of the sources of gamma ray for detection[19]. Other than using different radioactive source and detector, a different sensor model has also been used in the cargo scanning system. The linear pushbroom sensor model is used for such a gamma-ray scanning system. Using only the knowledge of the dimensions of a cargo container, we automatically calibrate the sensor and find all the sensor parameters, including the image center, the focal length, the 3D sensor starting location, the viewing direction, and the scanning speed. Then, a semi-automated stereo reconstruction approach is proposed to obtain 3D measurements of objects inside the cargo by using two such scanning systems with different scanning angles to construct a pushbroom stereo system[12].

5. CONCLUSION

Due to the vast nature of Indonesian geography, the possibility of human trafficking and smuggling of goods is greater. Gamma-ray for vehicle and cargo inspection is suitable to stop these contrabands, along with the common x-ray system. It is cheaper, having better penetration power, but at the same time, the radiation cannot be turned off as the x-ray did. This nature of gamma-ray's penetration results in producing a better image during the scanning process. At the same time, the safety aspect of the driver needs also to be considered. For the sake of safety, some existing equipment required the driver to go out from his vehicle, but this will be time-consuming. Another proposal is by limiting the gamma-ray itself, so it will only be directed in a certain direction. This study has set some of these requirements for such system, especially from the mechanic point of view, to facilitate both fast and safe examination in the Port.

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