The Cobalt-60 Container Scanner

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SUMMARY. The container(or cargo) scanners using digital radiography are very effective in the fight against contraband. This paper presents a special container(or cargo) scanner, which uses the commercial industrial radiography Cobalt-60 source of 100-300Ci. Depending on the adoption of high sensitive array detector, which is invented by INET, and other technical solutions, the characteristics of Cobalt-60 scanner are good enough for container(or cargo) inspection. Its "Contrast Indicator(CI)" and "Image Quality Indicator(IQI)" for 100mm steel are equal to 0.7% and 2.5% respectively and the "Steel Penetration(SP)" is about 240mm .The cobalt-60 container scanner is much cheaper and more reliable than those scanners using accelerator source, and its penetration ability is much better than that of x-ray machine scanner. The total composition, main difficulty and technical solutions, inspection characteristics and the application prospect of the Cobalt-60 scanner are presented with an emphasis.

1 INTRODUCTION

Since 1990, Schlumberger Industries (French) [1], Heimann Company(German) and Aerospace Company (British) have produced and sold several sets of container (or cargo) scanners using static or linear electron accelerator as high energy x-ray source. Tsinghua University (Chinese) also has researched and constructed one set of container or cargo scanner in Beijing, which x-ray source is a 9 Mev electron linear accelerator too [2].These scanners have very nice inspection characteristics and have been being strong weapons in the fight against drugs, arms and conventional contraband.

Nevertheless, these kinds of accelerator container scanner still have not been applied widely. The main reasons for such situation are as following :

a) Too expensive
The cost of the equipment is about ten million USD or more now.

b) Very high radiation intensity
The output of the accelerator used is as strong as 3000-4000 cGy/min.m. A lot of money have to be paid for shielding so strong radiation.

c) Large area
Because the length of inspection tunnel must be longer than 50m to prevent the radiation escape and the distance from accelerator target to array detectors is more than 12m, the total area of this kind of scanner is very large.

d) Complex maintenance
Especially for the accelerator , the maintenance is complex and difficult. The users have to pay 10-20% of the equipment cost per year for maintenance.

Therefore, a lot of work have been done to find out other container scanner designs which are much cheaper, easier to shield and can be installed in a much smaller area.

Several companies have tried to use x-ray machine as the radiation source. Nevertheless, because of the highest energy of the x-ray is just only several hundred keV, the steel penetration of these x-ray machine scanner is very poor($\leqslant$ 100mm steel).

The penetration ability of Cobalt-60 isotope source (E_r=1.17,1.33MeV) is much higher than that of x-ray machine and is similar to that of the electron accelerator of 4-5MeV. But the radiation output of ordinary radiography cobalt-60 source is much smaller than accelerator's. By using very high sensitive array detector , low noise level front-end circuit and special signal and image treatment method, we have successfully designed and constructed a Cobalt-60 scanner, which uses the widely adopted industrial radiography Cobalt-60 source of 100-300 Ci. The steel penetration and other characteristics of the Cobalt-60 scanner are similar to those of 4 ~ 5 MeV accelerator scanner, but its cost is much cheaper . It is easy to operate and maintain and only need much smaller area for installation and operation.

The following article will present the Cobalt-60 container scanner with an emphasis on the total composition , main difficulty and technical solutions , inspection characteristics and the application prospect.

2. SYSTEM COMPOSITION

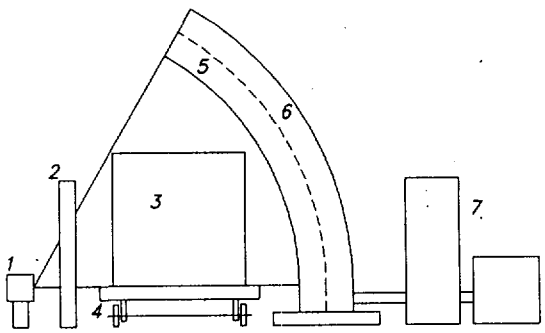

fig.1 system composition

The system composition of cobalt-60 container scanner is shown in fig 1. It consists of following main components:

a)Radiation source ①
The commercial industrial gamma radiography cobalt-60 source projector is used. The source activity is 100 ~ 300 Ci. The active dimensions of the source are ϕ 4 × 4mm. The total weight of the projector is less than 250kg. This kind of cobalt-60 source have been adopted widely in industrial non-destructive testing and have been proved to be very reliable, safe and convenient.

b)Front and back collimators ②⑤
The γ radiation of cobalt-60 source is collimated by the front and back collimator into a very thin slice type and then aims the array detector.

c)Conveyer system ④
It is used to pull the object-container to pass through the slice type radiation zone with a settled speed.

d) Array detector ⑥

The special gas-pressurized array ion-chamber invented by INET[3] is used. Because of special construction and gas-mixture, the ^{60}Co efficiency and sensitivity of this array detector are as high as 40% and 4×10^5pC/cGy respectively. This is the key technique of cobalt-60 container scanner.

e)Detection electronics and image processing subsystem ⑦

The very low noise front-end circuits are used to get large dynamic range . The signals are digitized on 16 bits after integration .The image processing subsystem acquires the digitized signals coming from the detection electronics, builds up the radioscopic images and displays them on the screen for examination by the operators.

3. THE MAIN DIFFICULTY AND THE TECHNICAL SOLUTIONS

The energies of ^{60}Co γ photons are never changed . Their intensity is also very stable in the period of measurement , because the half -life time of Cobalt-60 is as long as 5.3 year. The ^{60}Co gamma radiography projector possesses yet more merits , such as reliability, easier operation and convenient maintenance.

Nevertheless, the radiation output of the Cobalt -60 gamma projector with the activity of 100-300 Ci is much lower than that of the accelerator . It is equal to or less than 0.1% of the latter's. This is the main difficulty for cobalt-60 container scanner to possess nice inspection characteristics.

The main technical solutions of this difficulty are as follows:

a) The high efficiency and sensitivity array detector has been adopted.

As shown before , the efficiency and sensitivity of INET's gas - pressurized array ion-chamber for ^{60}Co γ -rays are equal to or higher than 40% and 4×10^5pC/cGy respectively. So the maximum signal current of the cobalt-60 scanner can be as large as several nA, and the statistical fluctuation can be kept low enough to insure nice inspection characteristics of the scanner.

b) The special low noise front amplifier has been designed and constructed. Its noise current level is less than 1×10^{-13}A. So the real total signal dynamic range of the measurement subsystem is higher than 2×10^4. This will deduce to nice contrast indicator and larger steel penetration.

c)Much shorter distance from source to array detector (e.g. 5-7m) can be chosen ,because the space distribution of Cobalt-60 gamma radiation is homogeneous .

d) The conveyer speed will be a little bit slower (e.g. 20cm/s).

Because the auxiliary inspection time of the Cobalt-60 scanner is much shorter than that of the accelerator scanner, its total throughput can be not less than the latter's in spite of the slower conveyer speed.

Depending on these technical solutions, the main difficulty of low radiation intensity is overcome and the inspection characteristics of Cobalt-60 scanner can be similar to those of the accelerator scanner.

4. MAIN INSPECTION CHARACTERISTICS

Five key indicators allow to quantify the performances of a radiation container scanner:

a) The "Image Quality Indicator (IQI)."
It is obtained by determining the diameter of the thinnest steel wire detectable behind a steel screen of a given thickness.

b)The "Contrast Indicator(CI)"
It represents the smallest overthickness detectable on a steel screen of a given thickness.

c) The "Steel Penetration (SP)"
It is the maximum thickness of steel behind which a totally absorbent object is still visible.

d) The "Maximum Dose Absorbed per Scanning"

e) The "Throughput " of radioscopy that can be achieved by the scanner.

The following performances of the cobalt-60 container scanner are achieved at INET (Tsinghua University):

-IQI: 2.5% behind 100 mm of steel
-CI: 0.7% behind 100 mm of steel
-SP: 240 mm of steel
-Maximum Dose per Scanning :0.02mGy
-Throughput : 20 40-foot containers per hour.

Fig.2 shows the radioscopic image of a motorcycle realized at the Cobalt-60 container scanner. A 1kg pack of sugar was hidden behind the oil box of the motorcycle, and is already visible on the image.

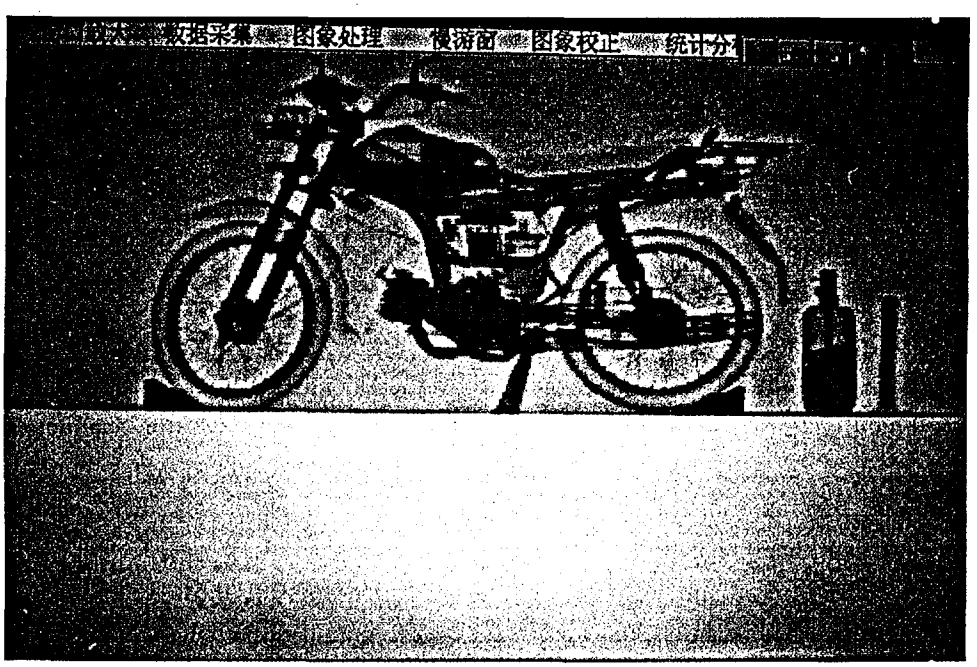

Fig.2 radioscopic image of a motorcycle

5. SPECIAL FEATURES AND APPLICATION PROSPECT.

A comparison of the inspection characteristics between the cobalt -60 scanner and the static accelerator scanner is shown in table 1.

Table 1. A comparison of inspection characteristics

indicator / scanner	IQI (100mm steel)	CI (100mm steel)	SP (steel)	Maximum Dose Absorbed per Scanning	Throughput
static accelerator scanner (2.5Mev)	2.5%	0.4%	240mm	0.4mGy	60 10-foot containers per hour
static accelerator scanner (5 Mev)	3%	0.75%	280mm	1mGy	20 trucks per hour
Cobalt-60 scanner	2.5%	0.7%	240mm	0.02mGy	20 40-foot containers per hour

As shown in table 1, the inspection characteristics of Cobalt-60 container scanner are similar to those of accelerator scanner. On the other side, the former possesses many other special features which are much better than the latter's :

a) Cheap price

The price of the Cobalt -60 scanner produced by INET will be about one or two tenths of the accelerator scanner's .

b) Low radiation intensity

Because the radiation output of the radiography Cobalt -60 source used is less than 0.1% of the accelerator's , the radiation protection problem is much easier to solve. There will be a lot of money to be saved on the radiation shielding building.

c) Small building area.

The inspection tunnel length of 6-8m is long enough for the Cobalt-60 scanner. The distance from source to detector is 5-7m. So the building area for Cobalt-60 scanner will be much smaller than that of accelerator scanner.

d) Simple operation and convenient maintenance.

The radiography Cobalt-60 source is easy to operate and maintain . So the operation and maintenance fee for Cobalt -60 scanner will be much lower.

e) Reliability and Stability

The energies of Cobalt-60 gamma rays are never changed and its intensity can also be considered to be constant during the scanning period . These are very beneficial for the signal and image processing . Because there is no high voltage, strong microwave and large electric power equipment etc. in the system , the cobalt-60 scanner is very reliable and stable .

Because of these special features and the nice enough inspection characteristics , the cobalt-60 container scanners are more suitable to be applied widely. This kind of scanner is satisfied for boundary customs, seaports, airports and railway stations etc..

6 CONCLUSION

A Cobalt-60 container(or cargo) scanner,which radiation source is a commercial radiography cobalt-60 source of 100-300Ci, has been designed and contrusted successfully by INET of Tsinghua University.

The inspection characteristics of this Cobalt-60 scanner are similar to those of the accelerator scanner. But its price is much cheaper and the building area needed for installation and operation is much smaller. The low radiation intensity, the simple operation and convenient maintenance, the reliability and stability etc. are the other merits of the Cobalt-60 container scanner.

The high properties and the low price will make Cobalt-60 container scanners have much better application prospect.

REFERENCE

[1] J.-F. Bouisset, A. Blis, A.-P. Lilot etc., "The Roissy - charles -de-Gaulle SYCOSCAN: a Reality"
in proceedings of the "Contraband and Cargo Inspection Technology" International Symposium Washington D.C. , October 28-30, 1992.

[2] AN Jigang, "Research and Construction of the Container Radiation Scanner"
Isotopes , Vol.8 . No. 1 p16-20(1995)(Chinese)

[3] AN Jigang, WU Heifeng , "Device of Gas Ionization Array Detectors for High Energy X or γ -rays Radiography", Chinese Patent.No. 93102728.4(1993)