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Analysis of Radiation Protection Detection Results of Some Container Vehicle Inspection System

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Abstract:

With the widespread use of X-ray vehicle inspection systems throughout the country, more and more vehicle transportation workers and equipment operators are exposed to radiation exposure, so the detection of radiation protection is of great importance. Based on the radiation protection testing results of some vehicle inspection systems in China in recent three years, the effects of accidental radiation on related employees were evaluated, and further guidance was provided for occupational safety protection of related workers. According to "Radiological Protection Requirements of Cargo/Vehicle Radiation Inspection System" GBZ 143-2015, dose equivalent rate around the boundary of radiation supervision area of X-ray vehicle inspection system, dose equivalent rate in control room and dose equivalent rate at driver's position were detected, and the detection results were analyzed and evaluated. From 2018 to 2020, detected nationwide 3 X ray radiation monitoring area border around the vehicle inspection system dose equivalent rate, control the indoor ambient dose equivalent rate and an ambient dose equivalent through the pilot position, test results show that the tested equipment radiation monitoring area boundary ambient dose equivalent rate up to 2.34 μSv/h, annual maximum growth rate of 13.33%;The maximum dose equivalent rate around the control room was 0.53μSv/h, and the maximum annual growth rate was 31.58%. The maximum dose equivalent was 0.083 μSV at the driver's position, and the maximum annual growth rate was 8.33%.The test results show that all inspection system testing results conform to the provisions on GBZ 143-2015, but with the increase of use fixed number of year, related equipment radiation increases slightly, and relevant personnel protective consciousness, protective measures do not reach the designated position, almost all is in a state of completely exposed, its radiation protection is of great urgency.

***Keywords**: Radiation, Vehicle inspection system, X-rays, Occupational exposure, Protection.*

I. INTRODUCTION

To effectively check the loading situation of the transported goods and improve the traffic efficiency of vehicles, X-ray vehicle cargo inspection system has been equipped in important sections such as borders, ports, customs and highways. The inspection system uses X-ray perspective imaging characteristics to

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automatically and quickly detect the loaded goods of passing vehicles, which effectively reduces the time of vehicle clearance inspection and the labor intensity of relevant employees, increases the accuracy of goods inspection, and greatly improves the clearance efficiency of vehicles passing through relevant inspection stations [1-3].

X-ray inspection of vehicles is based on X-ray perspective and imaging technology. The system consists of radioactive source system, vehicle positioning system, data collection system, imaging system and alarm system. In the process of passing vehicles inspection by the vehicle inspection system, X-rays will scatter, leak and spread to the surrounding environment, thus causing X-ray radiation to employees around. Therefore, it is vitally important to detect the radiation protection of X-ray vehicle inspection system, which is also of great practical significance to the health of relevant employees [4-6].

II. OBJECTS AND METHODS

2.1 Objects

Classified random sampling method, three X-ray vehicle inspection systems of different brands and models, such as a domestic port inspection station (IG-SCAN-MA2 electronic linear accelerator inspection system), a customs inspection station (CBD61-405 container vehicle inspection system) and a highway inspection station (CBD61-405 container vehicle inspection system), were randomly selected. For three consecutive years (2018, 2019 and 2020), the dose equivalent rate around the boundary of the radiation supervision area, the dose equivalent rate around the control room and the dose equivalent rate at driver's position of each inspection system were tested [7-8].

2.2 Methods

The above-mentioned vehicle inspection systems all belong to the combined mobile X-ray inspection system, with the maximum X-ray energy of 6MeV. The area 1m away from the central axis on both sides of the radiation source room and useful beam area is defined as the control area, and the supervision area is defined as a rectangular area with a length of 34m and a width of 10.5m around the shielding wall. The east shielding wall is made of 600mm concrete. The west shielding wall facing the beam-out direction is made of 900mm concrete, and the rest is made of 600mm concrete.

During the detection of the radiation level at the boundary of the supervision area of the inspection system, the radiation source was made stand still when the output parameters of the accelerator were adjusted to the maximum state, and the dose equivalent rate around the outer boundary of the supervision area was measured and recorded. See Fig 1 for the schematic diagram of the detection points. No.1 to No.5 are the northern boundary detection points. No.6 to No.16 are the eastern boundary detection points. No.17 to No.21 are the southern boundary detection points, and No.22 to No.32 are the western boundary detection points.

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The dose equivalent rate around the control room was detected. The dose equivalent rate around the control room and that at the operator's operating position were measured and recorded when the accelerator output parameter was adjusted to the maximum.

The dose equivalent rate at driver's position is detected once. When the accelerator's output parameter was adjusted to the maximum state, the inspection system scanned 20 times at the standard scanning speed, and the accumulated surrounding dose equivalent was measured and recorded.

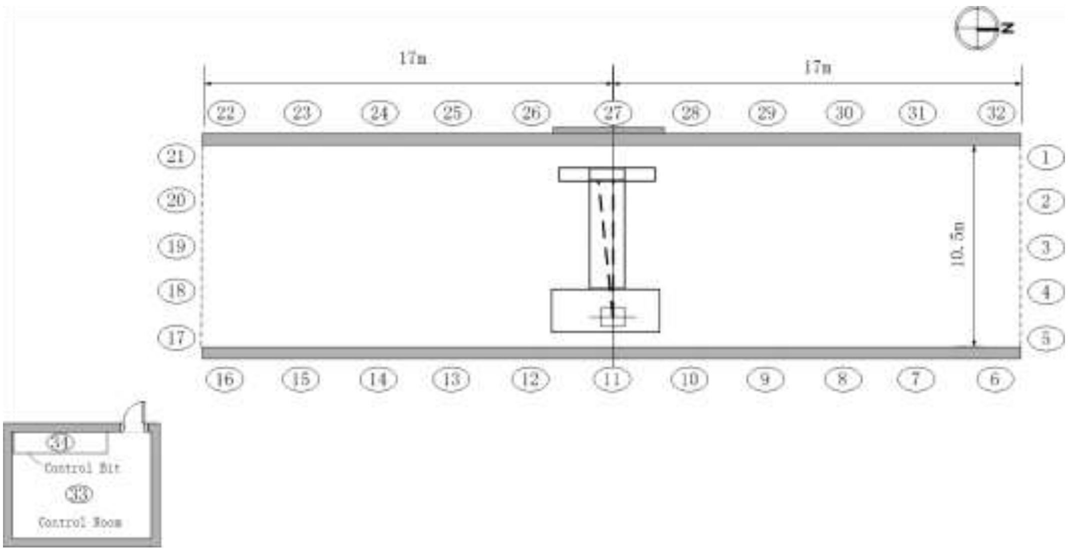

Figure 1 Inspection point layout diagram

III. TEST RESULTS

3.1 Radiation Supervision Area

According to the requirements of "Radiological Protection Requirements of Cargo/Vehicle Radiation Inspection System" (GBZ 143-2015), the dose equivalent rate around the boundary of radiation supervision area of vehicle inspection system should be no more than 2.5μSv/h. TABLE I to TABLE III show the inspection results of the boundary radiation rate in the supervision area of the X-ray vehicle inspection system of a port, a customs and a highway inspection station in China.

As can be seen from TABLE I to TABLE III, the maximum dose equivalent rate around the boundary of the supervising area is 2.34μSv•h^{-1}, which is smaller than the limit of 2.5μSv•h^{-1} specified in GBZ 143-2015; however, with the increase of the service life of the same X-ray vehicle inspection system, the dose equivalent rate around the boundary of supervision area will gradually increase, with the maximum growth rate of 13.33%; for the equipment that has been in service for a long time, such as the CBD61-405 container vehicle inspection system of a customs shown in TABLE II (put into use in 2012), its inspection value has significantly increased compared with that of the CBD61-405 container vehicle inspection system of a port shown in TABLE III (put into use in 2017), and the maximum difference rate in the same

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inspection year is 18.97%. Especially, the values of some inspection points are close to the standard limit, which indicates that the X-ray dosage there is on the edge of endangering relevant employees.

TABLE I. Dose equivalent rate around the boundary of supervision area of a port (μSv•h^{-1})

Inspection point	Inspection results in 2018	Inspection results in 2019	Inspection results in 2020
1	0.19	0.19	0.20
2	0.23	0.24	0.24
3	0.29	0.29	0.30
4	0.22	0.23	0.24
5	0.19	0.19	0.20
6	0.15	0.16	0.17
7	0.15	0.16	0.16
8	0.20	0.20	0.21
9	0.19	0.19	0.22
10	0.16	0.18	0.19
11	0.21	0.23	0.23
12	0.33	0.35	0.36
13	0.27	0.28	0.30
14	0.60	0.61	0.61
15	0.89	0.93	0.95
16	0.55	0.56	0.56
17	0.41	0.41	0.46
18	0.16	0.18	0.20
19	0.20	0.20	0.23
20	0.20	0.22	0.23
21	0.32	0.34	0.36
22	0.25	0.27	0.28
23	0.18	0.20	0.22
24	0.19	0.19	0.20
25	0.15	0.17	0.17
26	0.19	0.19	0.20
27	0.28	0.28	0.30
28	0.32	0.33	0.35
29	0.32	0.32	0.34
30	0.31	0.31	0.32
31	0.16	0.17	0.19
32	0.16	0.17	0.20

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TABLE II. Dose equivalent rate ($\mu Sv \cdot h^{-1}$) around the border of supervision area of a customs

Inspection point	Inspection results in 2018	Inspection results in 2019	Inspection results in 2020
1	2.20	2.21	2.22
2	2.20	2.22	2.22
3	1.90	1.94	1.96
4	1.80	1.82	1.85
5	1.70	1.72	1.73
6	0.52	0.52	0.55
7	0.79	0.86	0.86
8	0.83	0.90	0.91
9	1.00	1.19	1.22
10	1.20	1.28	1.29
11	2.30	2.33	2.34
12	1.30	1.32	1.36
13	1.10	1.28	1.30
14	0.88	0.91	0.92
15	0.79	0.93	0.95
16	0.55	0.56	0.56
17	1.90	1.91	1.96
18	2.00	2.08	2.10
19	2.00	2.02	2.03
20	2.00	2.02	2.03
21	2.00	2.04	2.06
22	0.36	0.37	0.38
23	0.74	0.72	0.72
24	0.66	0.69	0.70
25	2.00	2.02	2.03
26	2.20	2.21	2.21
27	1.80	1.83	1.90
28	2.20	2.20	2.25
29	2.10	2.10	2.12
30	0.79	0.80	0.80
31	0.74	0.76	0.76
32	0.39	0.41	0.41

TABLE III. Dose equivalent rate ($\mu Sv \cdot h^{-1}$) around the boundary of supervision area of an inspection station

Inspection point	Inspection results in 2018	Inspection results in 2019	Inspection results in 2020
1	0.21	0.21	0.22
2	0.20	0.22	0.22
3	0.19	0.20	0.20
4	0.19	0.21	0.21

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5	0.20	0.20	0.22
6	0.28	0.29	0.31
7	0.31	0.32	0.33
8	0.31	0.32	0.32
9	0.33	0.33	0.35
10	0.32	0.33	0.36
11	0.31	0.31	0.32
12	1.00	1.02	1.02
13	1.00	1.01	1.03
14	0.64	0.65	0.66
15	0.41	0.42	0.43
16	0.34	0.35	0.35
17	0.13	0.15	0.16
18	0.13	0.14	0.16
19	0.13	0.15	0.18
20	0.14	0.15	0.16
21	0.16	0.18	0.21
22	0.31	0.37	0.38
23	0.35	0.42	0.50
24	0.38	0.69	0.72
25	0.28	0.32	0.33
26	0.26	0.31	0.33
27	0.31	0.83	0.90
28	0.32	0.40	0.45
29	0.59	0.60	0.62
30	1.0	1.10	1.18
31	1.2	1.76	1.80
32	0.30	0.41	0.50

3.2 Control Room

According to "Radiological Protection Requirements of Cargo/Vehicle Radiation Inspection System" (GBZ 143-2015), the dose equivalent rate around the control room of the inspection system should be no more than 1.0μSv/h. TABLE IV to TABLE VI show the test results of radiation level in the control room of the X-ray vehicle inspection system of a port, a customs and a highway inspection station in China.

It can be seen from TABLE IV to TABLE VI that the maximum dose equivalent in the control room is 0.53μSv•h-1, which is smaller than the limit of 1.0μSv•h^{-1} specified in GBZ 143-2015; however, with the increase of the service life of the same X-ray vehicle inspection system, the dose equivalent rate in the control room will gradually increase, with the maximum growth rate of 31.58%; for the equipment with long service time, such as the vehicle inspection system of a customs shown in TABLE II, its inspection value is significantly higher than that of the vehicle inspection system of a port shown in TABLE III, and the maximum difference rate in the same inspection year is 66.67%.

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TABLE IV. The dose equivalent rate (μSv•h^{-1}) in the control room of a port

Inspection point	Inspection results in 2018	Inspection results in 2019	Inspection results in 2020
33	0.15	0.18	0.22
34	0.16	0.19	0.25

TABLE V. The dose equivalent rate (μSv•h^{-1}) around the control room of a customs

Inspection point	Inspection results in 2018	Inspection results in 2019	Inspection results in 2020
33	0.45	0.48	0.52
34	0.45	0.49	0.53

TABLE VI. Peripheral dose equivalent rate (μSv•h^{-1}) in the control room of a inspection station

Inspection point	Inspection results in 2018	Inspection results in 2019	Inspection results in 2020
33	0.15	0.17	0.20
34	0.15	0.18	0.20

3.3 Driver's Position

According to "Radiological Protection Requirements of Cargo/Vehicle Radiation Inspection System" (GBZ 143-2015), the dose equivalent rate at driver's position should be no more than 0.1μSv. TABLE VII

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to TABLE IX show the test results of the radiation level at driver's position of the X-ray vehicle inspection system of a port, a customs and a highway inspection station in China.

It can be seen from TABLE VII to TABLE IX that the maximum dose equivalent in the control room is 0.083μSv, which is smaller than the limit of 0.1μSv specified in GBZ 143-2015. However, with the increase of the service life of the same X-ray vehicle inspection system, the dose equivalent at the driver's position will gradually increase, with the maximum growth rate of 8.33%. For the equipment with long service time, such as the vehicle inspection system of a customs shown in TABLE II, its inspection value is significantly higher than that of the vehicle inspection system of a port shown in TABLE III, and the maximum difference rate in the same inspection year is 18.97%.

TABLE VII. Dose equivalent (μSv) rate at driver's position of a port

Inspection point	Inspection results in 2018	Inspection results in 2019	Inspection results in 2020
Driver's position	0.058	0.060	0.065

TABLE VIII. Dose equivalent (μSv) rate at driver's position of a customs

Inspection point	Inspection results in 2018	Inspection results in 2019	Inspection results in 2020
Driver's position	0.080	0.081	0.083

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TABLE IX. Dose equivalent (μSv) rate at driver's position of a inspection station

Inspection point	Inspection results in 2018	Inspection results in 2019	Inspection results in 2020
Driver's position	0.047	0.050	0.052

IV. DISCUSSION

1) The detected data of some X-ray vehicle inspection systems in China from 2018 to 2020 are in line with the radiation protection requirements of "Radiological Protection Requirements of Cargo/Vehicle Radiation Inspection Systems" (GBZ 143-2015), and all systems operate normally, safely and orderly.

2) The detected values of all tested equipment systems are increasing year by year in different degrees. With the increase of the service life of the equipment systems, the values of all testing points are also increasing. Therefore, it is very important to check the equipment systems every year. At the same time, the elimination system of equipment systems should be gradually implemented to ensure the health of relevant employees.

3) Although the detection results of points at driver's position all meet the requirements of GBZ 143-2015, most drivers lack safety protection awareness and measures, and are completely exposed to a large extent. Therefore, it is urgent to protect and educate drivers on radiation protection.

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