

# Betatron Application in Mobile and Relocatable Inspection Systems for Freight Transport Control

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**Abstract.** Accelerators with energy level up to 4 MeV having high level of penetration ability by steel equivalent are the popular to control oversize cargo transported by road, by railway and by river. Betatron's usage as cyclic induction accelerator has some advantages in comparison with linear accelerators and other sources. Tomsk Polytechnic University has developed many types of betatrons, most of them are being produced by separate affiliated company "Foton". Article is shown the results of application of the betatrons in inspection custom systems.

Inspection systems using X-ray units and accelerators of ionizing radiation is one of the most rapidly developing directions in digital radiography during the last decades. Accelerators with energy level up to 4 MeV having higher level of penetration ability by steel equivalent are the most popular to control oversize cargo transported by road, by railway and by river.

Betatron's usage as cyclic induction accelerator has some advantages in comparison with linear accelerators and other sources. Betatron has a small focal spot which improves the resolution of the system. Narrow-beam betatron radiation is easy to collimate so a spurious background of scattering radiation is much lower than in the systems based on other sources. The energy of accelerated electrons could be regulated in relative units from about 0.3 to 1. Moreover, the betatron control system allows programming the radiation spectrum which could be used to determine the density of the scanned object. Tomsk Polytechnic University has developed many types of betatrons, most of them are being produced by separate affiliated company "Foton". Technical specifications of betatrons for using in customs inspection systems are shown in Table 1.



**Table 1.** Technical specifications of betatrons

Parameters	MIB-2.5	MIB-5	MIB-7.5	MIB-9
Peak energy of bremsstrahlung radiation, MeV	1 – 2.5	2 – 5	2–7.5	2–9
Peak dose rate at 1m from the target, cGy/min	2	4	7.5	20
Pulse repetition rate, Hz	400	400	300	400
Power consumption, kVA	2	3	3	5
Radiator weight, kg	57	80	115	150
Total weight of units, kg	120	180	220	260
Size of focal spot, mm	0.25×2	0.25×2	0.25×2	0.25×2
Maximal controlled thickness (of steel), mm	150	200	270	330
Dimensions of the radiator, mm	Ø320×220	Ø360×230	Ø380×315	Ø450×340
Angle of beam in a vertical plane, deg	60	52	52	60

All betatrons, designed for inspection systems, have separate radiator with cylindrical – shaped form. This form minimizes radiation protective shielding. External views of radiators are shown on figure 1 and figure 2.

**Figure 1.** Betatron MIB-5.**Figure 2.** Betatron MIB-9.

Customs inspection system, based on two accelerators with energy of 7.5 MeV, started to work in Bangunan Sultan Iskandar in BuHit Chaqar, November, 2012. This complex is supposed to control 180 trucks per hour or 2000 – per day.

This system has high scanning speed – up to 15 km/h, that was achieved by using ionizing radiation detectors of high-performance as well as the latest algorithms of data processing. This system also allows getting three-dimensional shadow images to increase the efficiency of freight inspection. External views of an inspection system are shown on figure 3.



**Figure 3.** Custom inspection system in Bangunan Sultan Iskandar in BuHit Chaqar, based on two betatrons with energy of 7.5 MeV.

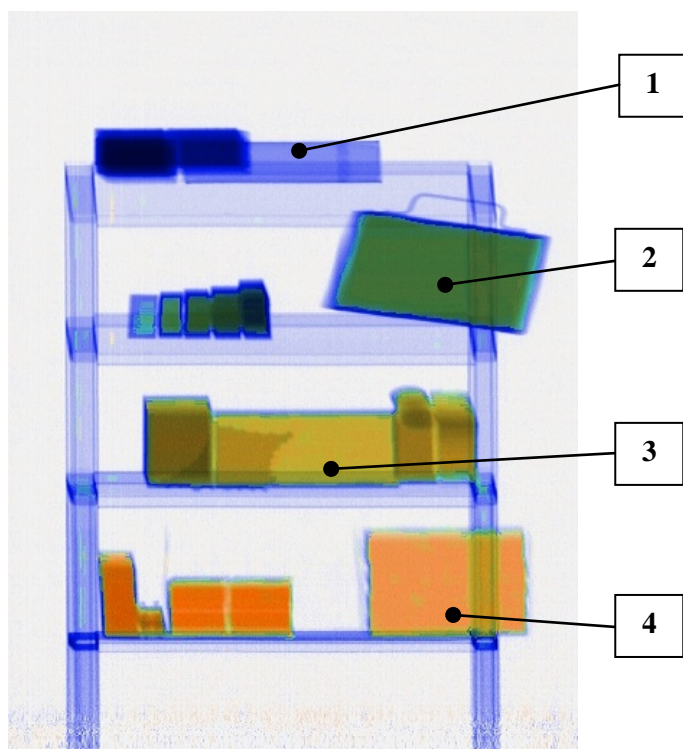
One of the most important advantages of this system is low dose rate on the object of control. It is about 50 microrentgen per one scanning. This parameter is close to normal radiation background. This can be possible because of low dose rate of betatron and high sensitivity of the detector array. Comparison with different customs inspection systems can be seen in Table 2.

In the future, the use of betatron with dual-energy mode will make possible to recognize materials contained in the test object. This technology could improve the information content of the entire complex and would enable to identify the explosives and drugs with higher effectiveness.

**Table 2.** Comparison with different customs inspection systems.

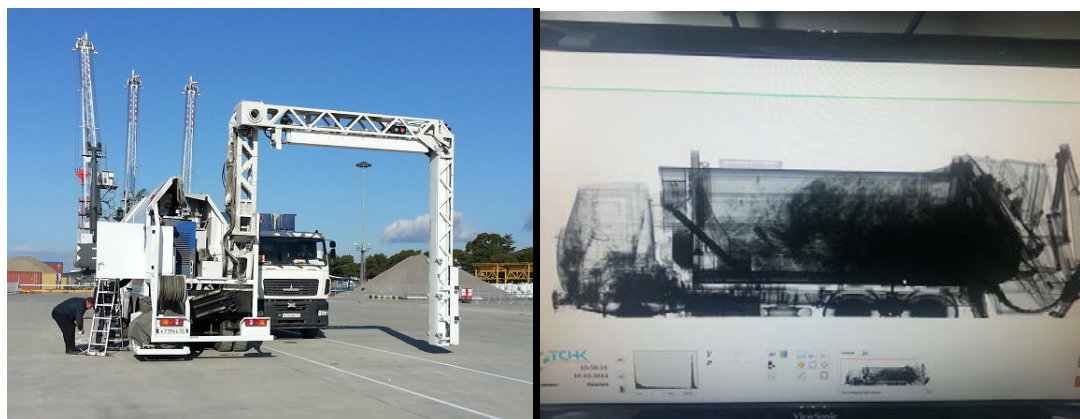
Parameters	Rapiscan Eagle	Silhouette Scan Mobile CaB 2000	HCV-Mobile	DRS CargoScan 5000M	System in BuHit Chaqar
developed by	Rapiscan security Products (USA)	Smith Heimann (Germany)	Smith Heimann (Germany)	Adani, TPU (Russia, Belorussia)	TPU, Power Scan, (Russia, China)
maximum thickness of penetration in steel, mm	300	110	180 (270)	300	250
resolution, mm	3	3	3	2.5	5
sensitivity, %	2	No data	No data	3	2
scanning speed, m/s	0.3	1	0.2	0.4	3
x-ray source	6 MeV linac	3 MeV betatron	3(4) MeV linac	5 MeV betatron	7.5 MeV betatron
dose per one scanning, mR	3	0.15	1(2)	No data	Less than 0.05
type	Relocatable	Mobile	Mobile	Mobile	Relocatable

Developing and improving the accelerator's dual-energy mode to increase efficiency in identification and detection materials prohibited for transportation, is carried out on the experimental platform – the ICC, Tomsk Polytechnic University. Algorithms and operating modes tested on the platform are applied and mastered in the operating complex. On a pictures below some results of using betatron in dual-energy mode it can be seen (figure 4).



**Figure 4.** Scanning in dual-energy mode: 1 – Lead; 2 – Steel; 3 – Aluminum; 4 – Plexiglas.

Aslo, MIB – 9 betatron was used in mobile inspection system ASD – 65201, which had successfully passed probational tests, working in Adler, Sochi, during Olympic Winter Games 2014.



**Figure 5.** Mobile inspection system in work during Olympic Winter Games 2014 in Sochi, Russia.

In summary, it is worth to say, that betatron is a good choice to be considered as a x-ray source in customs inspection systems, and this is an optimal decision for using in mobile and in relocatable inspection systems.

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