

SMALL-SIZE BETATRON FOR THE ENERGY 2.5 MEV FOR FIELD INSPECTION

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The report presents the main characteristics of a betatron for the peak energy 2.5 MeV – MIB-2.5D (PXB-2.5D). The unit is designed for field inspection of products with the equivalent steel thickness 120 mm.

Small-size betatrons as X-ray sources for non-destructive testing have certain advantages over other accelerators and radionuclide sources. They have a rather high radiation energy, small focal spot, possibility to adjust the maximum energy, and continuous bremsstrahlung range. Besides, the energy being the same, betatrons are smaller in size, lighter and much cheaper than microtrons or linear accelerators. Radiation safety issues are easier solved for small-size betatrons rather than for radionuclide sources [1, 2].

Low radiation dose rate is the betatron's weak point, that is why betatron developers have always aimed at increasing it. In the recent models of small-size betatrons, the dose rate has increased 15-20 times compared to the first units, the dimensions and weight being the same.

As sensitive equipment for radiation detection is developing (digital radiography, scanning systems with scintillation detector lines), the lower dose rate is becoming less significant. These two opposite factors significantly extend the sphere of betatron application.

A more widespread use of betatrons in cargo inspection facilities for vehicle examination is an example [3, 4]. The number of such facilities has risen to above 100.

At present, small-size betatrons for 4 MeV (MIB-4), 6 MeV (MIB-6), and 7.5 MeV (MIB-7.5) are widely used to X-ray materials and products. Depending on the energy, they allow X-raying products of the equivalent steel thickness from 150 to 250 mm. Betatrons of that kind in the amount of 15-20 units per year are sold both in Russia and abroad. John Macleod Electronics Ltd (Great Britain) is a betatron dealer covering European countries and United States. It also performs service maintenance of betatrons. MIB-4, MIB-6 and MIB-7.5 models can be used in transient conditions, however a rather large weight of 65 kg (MIB-4) to 110 kg (MIB-7.5), and overall weight being 120-180 kg, makes it more difficult to use them. As a rule, in transient conditions these units are mainly used in emergency situations.

Many Western companies specializing in NDT of pipelines, bridges and buildings under construction have addressed JME asking to supply a betatron for replacement of radionuclide sources to be used in field conditions. RII and Foton Ltd have joined their efforts to develop a betatron of that kind. The major task was finding a compromise between the dose rate, unit weight and consumed power.

The developed betatron is named as MIB-2.5D for the Russian market, and PXB-2.5D (portable X-ray betatron) when exported.

Brief technical characteristics of the betatron are given below.

1. Peak energy of accelerated electrons	2.5 MeV
2. Adjustment range of the energy of accelerated electrons with 0.1 MeV steps	1.0...2.5 MeV
3. Guaranteed bremsstrahlung dose rate at 1 m distance from the target, at the peak energy	0.7 R/min
4. Maximum size of the focal spot	0.2×2 mm
5. Maximum power consumption from AC mains at 50, 60 Hz, voltage 220 V with permitted deviations from the nominal value $\pm 10\%$, not more than	0.8 kW
6. Betatron operation cycle is 60 min of operation, 15 min of interval with fans on	
7. Minimum size of the work field at 1 m focal distance and darkening non-uniformity not more than 10%	350×350 mm
8. Relative radiographic sensitivity for steel at more than 50 mm thicknesses (D7 film with lead shields), focal distance 1 m, optical density 2.5	1- 1.5 %
9. Dimensions of units, mm:	
radiator	440×300×150
pulse converter	415×205×240
power supply unit	445×245×390
control panel	235×200×115
remote dosimeter	70×53×26
unit of visual alarm	Ø 140 ×80
10. Weight of betatron units, not more than, kg:	
radiator (without support)	30
pulse converter	10.5
power supply unit	20
control panel	1.5
remote dosimeter	0.3
unit of visual alarm	1.5

Structurally the betatron consists of five units: radiator, pulse converter, power supply unit, control panel and remote dosimeter. Figs. 1 and 2 show the radiator and control panel.

The pulse converter contains injection, expansion and contractor systems, as well as a converter to supply those systems. Departure from traditional arrangement of injection, expansion and contractor systems inside the radiator is a result of the necessity to minimize weight and dimensions of the latter.

The power supply unit contains rectifier and power factor corrector (PFC), current pulse generator to feed the electromagnet, and module of automatic control system. PFC presence allows supplying betatron in field conditions from a self-contained power source (usually petrol-electric generating set) without the required significant reactive power allowance.

The automatic betatron control system provides input of the source data (setting of the energy of accelerated electrons, exposure time, output dose and dose behind the test object), adjustment of the accelerator for maximum radiation, diagnostics of the operating modes of betatron units, automatic shutdown as per the source data. The unit is equipped with a remote dosimeter that allows setting a correct exposure the absorber thickness being unknown.

It is recommended to use MIB-2.5D for X-raying welding joints and castings from 30 to 120 mm thick in steel, as well as building constructions of concrete and other materials from 100 to 300 mm thick. An exposure nomogram for steel is shown in Fig. 3.

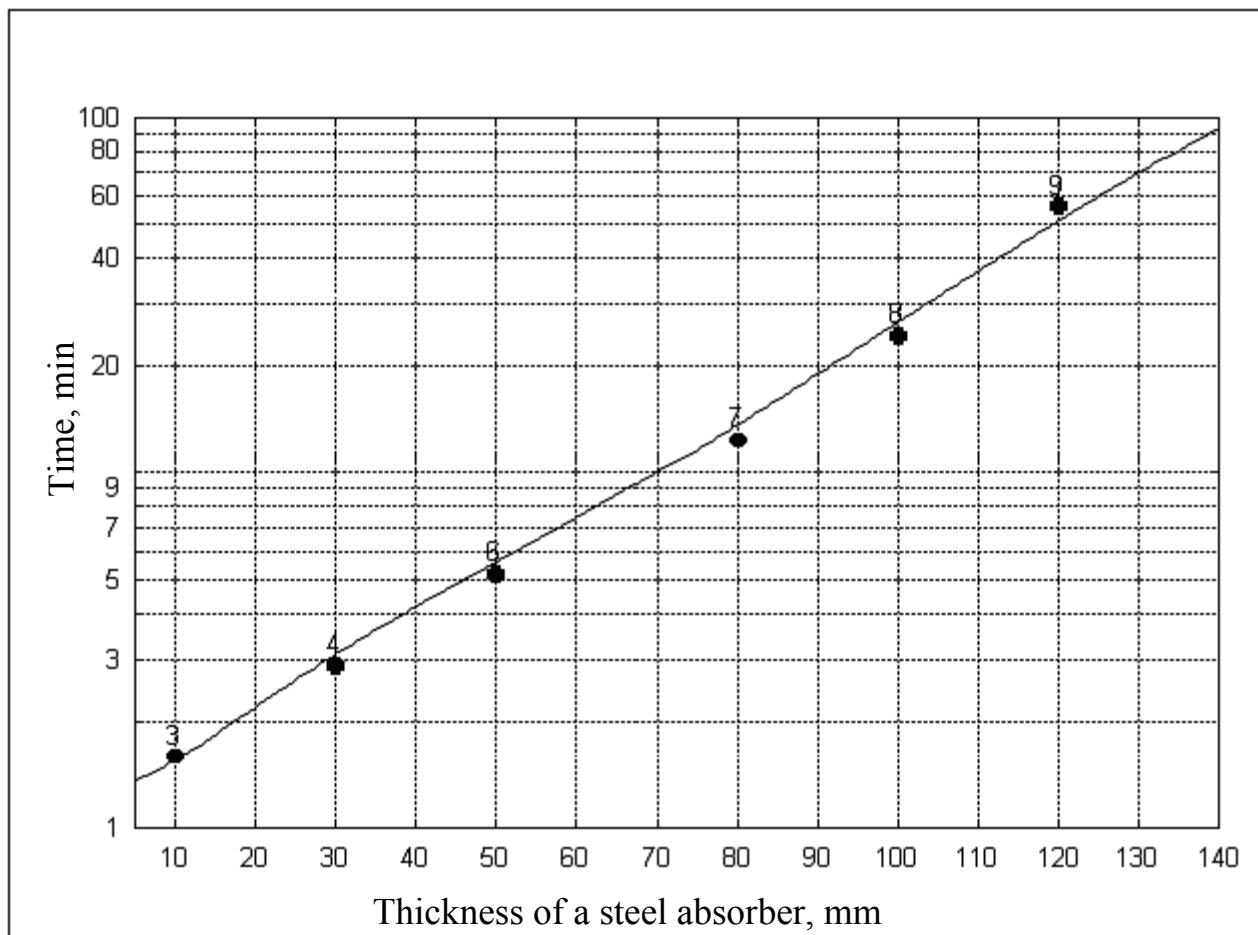


Fig. 3. Exposure chart for steel (focal distance 1m, D7 film, optical density 2,0, charging 0,5 Pb Film 1.0 Pb)

Starting from 50 mm steel thickness, MIB-2.5D in its characteristics is superior to the best types of X-ray units. If we compare one of the latest models of YXLON International company recommended for field operation, namely 300 kV Y.SMART 300HP [5] unit, we have the following results. The weight of X-ray and betatron radiators is about the same (30 and 33 kg respectively), power consumed is also similar (800 and 900W). The exposure time during X-raying steel absorber 50 mm thick is the same however X-ray unit manufacturer claims the maximum X-rayed thickness 65 mm, whereas for betatron this number is 120 mm. Moreover, focal spot sizes in betatron are much smaller than in an X-ray device.

In conclusion, the armoury of NDT instruments in field conditions has renewed with another X-ray source, the use of which is most expedient for the range of thicknesses from 50 to 120 mm of steel.

References

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