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Monitoring of Performance of Diagnostic X-Ray Apparatuses under Working Conditions

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In recent years, a new generation of X-ray diagnostic apparatuses (XRDA) for monitoring of output parameters became widely used worldwide. Such XRDA models can be connected directly to a PC to provide calculation, graphical presentation, and storage of XRDA parameters. In 2013, foreign apparatuses for monitoring of output parameters were replaced on the local medical market by domestic XRDA certified in the Russian Federation. Since October 2013, modified UKREKh devices with Hamamatsu S8193 detectors became available from the Scientific-Practical Center of Medical Radiology. The main specifications of the portable autonomous apparatus Cobia and the modified apparatus UKREKh are presented in this work. The competitiveness and efficiency of the modernized UKREKh device in terms of repair and installation are demonstrated as compared to foreign models of radiation kilovoltmeters.

Rapid progress in development of X-ray diagnostic apparatuses is due to introduction of computer technologies to medical imaging. This constantly increases the stringency of requirements for the quality of monitoring of their parameters. In addition to digital apparatuses, combined systems are widely used in X-ray diagnosis: SPECT-CT, CT-MRT, etc. Use of such systems can lead to high radiation load on patients and personnel. In X-ray apparatuses, 3-phase generators are replaced by semiconductor systems with power frequency modification and stabilization at the 4% level. Genetically significant X-ray load on the population is increasing (1% per year). The X-ray dose in X-ray diagnostic apparatuses is determined by tube voltage, which requires accurate control. Such control is implemented by radiation kilovoltmeters (X-ray testers).

In recent years, a new generation of X-ray diagnostic apparatuses (XRDA) has been introduced worldwide to medical practice for monitoring of output parameters of X-ray apparatuses. Such XRDA models can be connected directly to a PC for calculation, graphical presentation, and storage of XRDA parameters. Examples of such apparatuses are universal X-ray dosimeter Unfors Xi (Unfors Instruments, Sweden) and X-ray testers UKREKh (Russia) with possibility for connection to a PC (since 2013). As noted above, these apparatuses represent a new generation of X-ray diagnostic systems – digital X-ray apparatus for roentgenography and roentgenoscopy and computer tomographs. They are powered from high-frequency anode voltage generators with low error.

In addition to such PC-connected devices, autonomous portable apparatuses for XRDA monitoring are also available on the medical instrument market. The Mult-o-Meter dosimeter (Unfors Instruments, Sweden) and domestic X-ray tester UKREKh are among examples of such apparatuses [1]. A total of 300 UKREKh apparatuses have been supplied by the Scientific-Practical Center of Medical Radiology to various medical institutions. These apparatuses are used in many regions of the Russian Federation [3].

In 2013, new models of foreign apparatuses for XRDA monitoring (both portable and universal) certified in the Russian Federation became available on domestic medical market.

The Unfors Xi universal dosimeter available on the market in 2010-2012 has been widely replaced by the universal PC-assisted dosimeter Piranha for XRDA expertise (roentgenographic, roentgenoscopic, mammographic, dental, CT) available from RTI Electronics AB (Sweden).

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Table 1. Comparative Parameters of Radiation Kilovoltmeters

Type of device	Anode voltage	Dose	Dose power	Exposure time	Note
Cobia	(38-153 kV) ± 12.5%	(400 μGy-1000 kGy) ± 5%	(15-100 μGy) ± 5%	(0.1 msec-2000 sec) ± 3%	Dose power is calculated from *D* and *Te*
UKREKh (2013)	(40-150 kV) ± 3%	(1.5 μGy-0.6 Gy) ± 10%	(1-400 R/min) or (0.15-60 mGy/sec) ± 10%	(10 msec-10 sec) ± 3%	Dose is calculated from *D* and *Te*

Since 2010-2012, the Mult-o-Meter dosimeter had been replaced on the domestic medical market by the Cobia autonomous portable dosimeter (RTI Electronics AB, Sweden).

Since 2013, modified UKREKh dosimeters with Hamamatsu S8193 detectors became available from the Scientific-Practical Center of Medical Radiology. The S8193 X-ray detector is a plane silicon photodiode with ceramic GOS scintillators. Independence of dosimeter parameters on working conditions is the main advantage of this dosimeter. This provides high stability of UKREKh performance in terms of dosimetric range and monitoring accuracy.

The main specifications of the Cobia autonomous portable dosimeter and modified UKREKh apparatus are given in Table 1.

In the UKREKh universal X-ray tester assisted by a PC (Fig. 1), Hamamatsu detectors are also used.

A PC connected to the UKREKh allows the tested parameters (anode voltage, output detector signal dose power) to be visualized in graphical form and various processing algorithms to be implemented. The data can be stored for further analysis. These advantages are achieved without considerably increase the cost of the device.

Portable PC, notebook, or netbook with Microsoft Windows XP, Vista, or Windows-7 can be used together with Excel spreadsheet or Net-Framework envelope.

The PC is connected to the UKREKh with RS-232/RS-232 (COM-1) cable, RS-232/USB connector, or Bluetooth interface instead of RS-232. The dotnet (.NET) technology in C# language provides connection to the PC. The software is for Visual Studio 2008 and envelope .Net Framework.

Monitoring data provided by the UKREKh device are transmitted to the PC. Upon processing, the following parameters are reported on the PC display:

– X-ray tube anode voltage *kVp* (mean peak *kVp*, kVp_{ecv} – equivalent to constant voltage according to IEC 61676);

– exposure dose power (radiation yield), R/min or mGy/sec;

– exposure dose, mR or mGy;

– exposure time: 10-10000 msec;

– half-value layer HVL;

– temporal *kVp* curve;

– temporal dose power curve in two detectors.

The working program window on the PC monitor at the end of exposure is shown in Fig. 2. The program interface is controlled by a mouse.

The Ueq voltage can be estimated from *Ua* array as peak voltage (constant voltage) in accordance with IEC 61676.

Fig. 1. General view of UKREKh.

Fig. 2. Working program window on PC monitor.

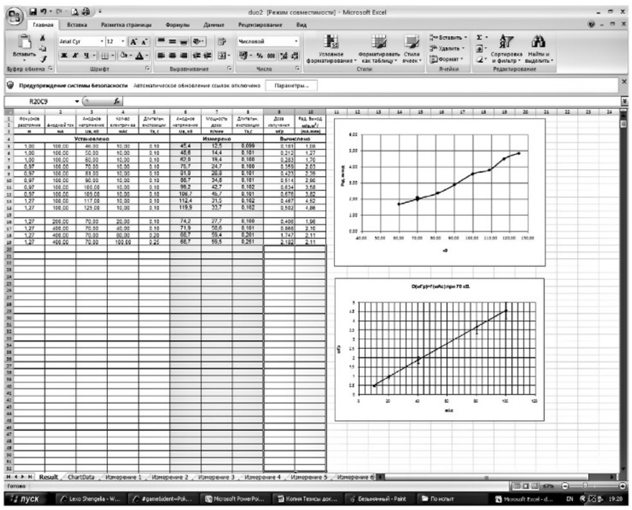

Fig. 3. Table of electrical and radiation parameters of UKREKh on PC monitor.

The data can be exported to Excel and presented as a table. Each new measurement is stored in a separate line of the table. The testing data are stored in numerical format, thus allowing automated processing of the data in the Excel program.

Based on the results presented as a dynamic table of the electrical and radiation parameters of the X-ray tube (Fig. 3), the real-time dependence of radiation dose on electricity can be obtained automatically. Radiation yield for a given anode voltage can also be estimated, as well as the relative measuring error. This allows the parameters of the power source and the X-ray radiation source to be estimated directly in a medical organization.

The accumulated experience in the use of UKREKh in combination with a PC corroborated these advantages [4]. The modernized UKREKh device has been shown to be effective and competitive as compared to foreign models of radiation kilovoltmeters.

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