

# SMART IONIZATION CHAMBER FOR GAMMA-RAY MONITORING

by

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A design and implementation of a smart ionization chamber suitable for connection into gamma radiation monitoring networks is presented in this paper. The smart ionization chamber consists of air-equivalent one liter ionization chamber with associated electronics and a built-in memory for storage of electronic data specifications. Generally, operating and measurement characteristics of the used ionization chamber are written into the memory chip attached to the chamber. A microcontroller-based data acquisition system with a mixed-mode interface has been implemented for the purpose of reading electronic data specifications from the memory chip, and for configuration and interfacing of the ionization chamber to the monitoring network using plug-and-play concept. The details of smart ionization chamber implementation and test results are included in the paper.

*Key words:* smart sensor, ionization chamber, interfacing, network, IEEE 1451, TEDS

## INTRODUCTION

A monitoring network with remote sensing technology should be used in order to provide for timely protection and minimal individual exposure in an unexpected event of a nuclear accident with release of radiation at nuclear facilities. Although sensor networks, especially wireless sensor networks, are considered one of the key technologies of the 21<sup>st</sup> century, these still have not found their full application in the radiation monitoring field. Main reasons for this situation originate in the fact that the contemporary radiation monitoring systems use very little or hardly any plug-and-play (PnP) technology, otherwise present in the computer industry. At the same time, there are no commercially available radiation detectors capable of PnP connection to multivendor networks.

In order to apply PnP concept in the field of the monitoring and sensor networks, it is necessary that individual devices, such as radiation detectors, include “self-describing” features that provide the most important information about the device. Based on this information it is possible to identify the devices connected to the network and communicate with them through standardized communication interfaces using standardized communications protocols. Due to the development of sensing technology in the last decade, smart sensors that contain a “self-describing” feature

emerged on the market [1-4]. Such sensors include data in a form of a transducer electronic data sheet (TEDS) located in the sensor.

With the aim to define a standard for a networked smart transducer and to provide for interoperability of equipment from various vendors, the IEEE 1451 set of standards has been proposed, with the expectation that it would be well received by both the producers and the users of sensing networks technology [5, 6]. In addition to the Smart Transducer Interface Standards, ANSI/IEEE N42.42 standard is proposed, which specifies the data format that should be used for all data available at the output of radiation measurement instruments. The N42 data format is aimed at facilitating manufacturer-independent transfer of information from radiation measurement instruments [7].

Ionization chambers are very convenient for continuous monitoring of ambient gamma dose rate in vicinity of nuclear facilities, as well as in medical facilities, industrial X-ray facilities and in radiography. The wide use of the ionization chambers in the systems of the kind is based on their good measurement characteristics, high reliability and relatively low cost. The ionization chambers have approximately uniform response in a wide range of gamma and X-ray energies, provide for precise discrimination between beta and gamma components of a radiation, and represent the best choice for measurement of high levels of gamma radiation.

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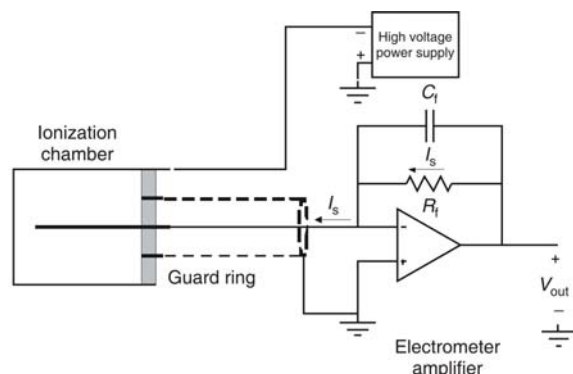
The objective of this paper is to develop smart, network capable ionization chamber that would lead to self-configuration of monitoring system based on this type of detector. The goal is to advance the PnP concept in the field of radiation monitoring by developing an electronic data specification corresponding to dc current type ionization chambers, so that a monitoring system could be implemented and configured quickly and easily and without errors which often occurs when a system is configured manually. Based on the literature that was available to the authors, there has been no attempt to make use of the PnP concept in interfacing of radiation detectors with built-in electronic sensor specifications.

This paper is organized in the following way: the section Interfacing of Smart Ionization Chamber provides both a concept and details of interfacing of smart ionization chamber and description of electronic data specification of ionization chamber. The section Proposed Electronic Data Sheet for ionization chamber focuses on the systematization of ionization chamber characteristics and a design of TEDS template for the ionization chamber. Experimental results are presented in the section Testing of Smart Ionization Chamber. Finally, the conclusions are given in the last section.

## INTERFACING OF SMART IONIZATION CHAMBER

Current type ionization chamber used in this study measures the average ionization produced by incoming radiation. This is achieved by measuring direct current (DC) generated in the chamber using electrometer amplifier. Conceptual design of operational amplifier based electrometer for current to voltage conversion is shown in fig. 1.

Major design difficulty in application of ionization chamber is a precise measurement of small currents whose magnitudes are of the order  $10^{-13}$  A. The extremely low current generated by radiation inside



**Figure 1. Interfacing of ionization chamber with amplifier based electrometer for current to voltage conversion**

the chamber imposes the use of highly sophisticated guarding techniques and an ultra low input bias current operational amplifier in order to make the entire system usable in environmental monitoring [8].

At equilibrium, a constant voltage  $V_{out}$  is developed across the known resistance  $R_f$ , which is given by  $V_{out} = R_f I_s$ . In this way, saturated ionization current  $I_s$  can be measured by measuring the voltage  $V_{out}$ . When the ionization current  $I_s$  is known for an air-equivalent ionization chamber, the exposure rate is given by the ratio of ionization current  $I_s$  and the mass  $M$  contained in the active chamber volume

$$\dot{X} = \frac{I_s}{M} \quad (1)$$

The air mass  $M$  is calculated from the values of the chamber volume and the density [8]

$$M [\text{kg}] = 1.293 V \frac{P}{P_0} \frac{T_0}{T} \quad (2)$$

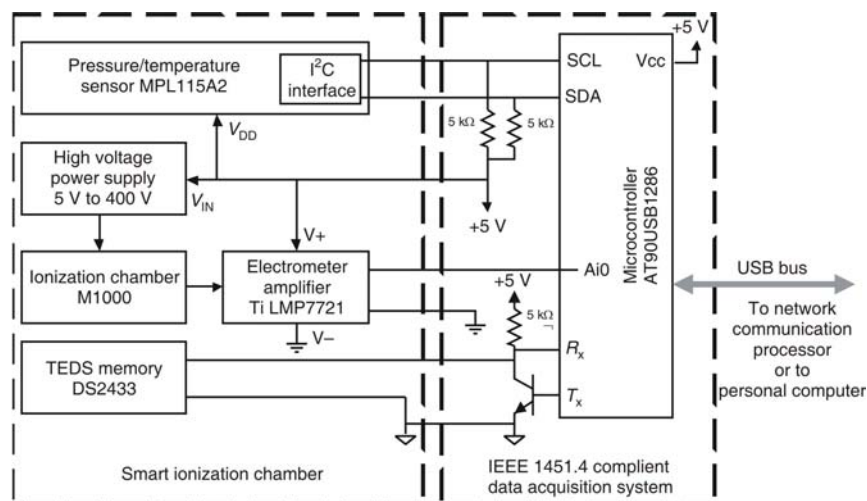
where  $V$  is the chamber volume in  $\text{m}^3$ ,  $P$  – the air pressure within the chamber,  $P_0$  – the standard pressure (101.325 kPa),  $T$  – the air temperature within the chamber, and  $T_0$  – the standard temperature (273.15 K).

Ionization chamber represents an analog transducer because its output provides only the analog measurement signal. In order to add “intelligence” to the analog ionization chamber it is necessary to include electronic data specification with most important electrical and measurement characteristics of the ionization chamber. This is achieved by attaching a small semiconductor memory to the ionization chamber. In this study, the ionization chamber specifications in the form of transducer electronic data sheet (TEDS) and the transmission of digital data between memory chip and data acquisition system (DAQ) are accomplished in compliance with IEEE 1451.4 standard [9], as shown in fig. 2.

The air-equivalent ionization chamber M1000 manufactured in Vinča Institute of Nuclear Science, Belgrade, Serbia, is used for the realization of the smart ionization chamber in this work. The ionization chamber was built on the basis of the concept of Novković *et al.* [10]. The ionization chamber is powered by 5 V obtained via USB bus. This voltage is converted to a 400 V by using a combination of boost converter and voltage multiplier [11]. Electrometer amplifier is designed using an ultra-low bias current op amp Ti LMP7721.

As suggested in eqs. (1) and (2), the exposure rate of air-equivalent ion chamber depends on the ambient temperature and pressure. Therefore, a digital temperature and pressure sensor with I<sup>2</sup>C interface is embedded in the smart chamber to provide corrections to ambient conditions.

Data acquisition system (DAQ) is based on a low-cost 8-bit microcontroller with USB, I<sup>2</sup>C and



**Figure 2. Block diagram of the smart ionization chamber connected to the IEEE 1451.4 compliant data acquisition system**

UART communication interfaces and 10-bit analog-to-digital converter (ADC). DAQ system performs multiple tasks: communications over mixed-mode interface (MMI) with TEDS memory, the analog signal processing and conversion, temperature and pressure sensor readings, and USB communication with PC or network processor. After connecting the smart ionization chamber to the DAQ system, the microcontroller detects presence of TEDS memory and reads ionization chamber specifications. Digital data transmission between TEDS memory and DAQ system is accomplished by means of *One-wire protocol* [12]. One-wire protocol uses just one wire for serial data transfer and power supply for the TEDS memory chip.

Analog voltage output of electrometer amplifier is converted to a digital signal using the ADC embedded in the microcontroller. Digital signal, measured at the electrometer amplifier output, is converted to an appropriate exposure rate based on the ionization chamber's calibration factor previously read from TEDS memory. Since the ionization chamber is equipped with the digital temperature and pressure sensor, the microcontroller is used to acquire ambient parameters through I<sup>2</sup>C interface, and perform measurement corrections to the ambient conditions. The resulting value of the exposure rate is sent to the communication processor using a USB interface.

The TEDS, attached to the ionization chamber, is implemented in accordance with the IEEE 1451.4 standard. The TEDS is divided into three major sections: Basic TEDS, Transducer TEDS and Calibration TEDS (fig. 3). Basic TEDS is mandatory, while other TEDS sections are optional.

The size of the Basic TEDS is 64 bits, and it contains the basic information about the transducer: Manufacturer identification, Model number, Version letter, Version number, and Serial number. It is possible to perform a unique identification of a sensor on the basis of the data from the Basic TEDS. The data in this sec-

Basic TEDS	Manufacturer ID Model number Version number Version letter Serial number
Transducer TEDS	Measurement range Output signal range Sensitivity Power supply ...
Calibration or correction TEDS	Calibration or correction data in a table format

**Figure 3. Structure of TEDS for ionization chamber**

tion of the memory is defined by the manufacturer and the user is not able to change it.

The Transducer TEDS section contains electrical and measurement characteristics of the given sensor, for example the measurement and the output signal ranges, sensitivity, power supply requirements, etc. The data, acquired by reading of TEDS memory, are used in the automatic detector configuration. The TEDS memory may also contain calibration data stored in the memory's third section.

In order to keep memory usage requirements low, TEDS bit mapping is accomplished through the concept of templates [9]. Transducer type templates have been standardized in IEEE 1451.4 for a wide selection of sensors, such as accelerometers, strain gauges, thermocouples, etc. However, this standard does not offer template for ionizing radiation sensors, thus significantly hampering the implementation of the IEEE 1451.4 standard in a network interfacing of radiation sensors.

The TEDS template for the ionization chamber has been proposed and implemented in this work. Readout of the ionization chamber TEDS data is performed by means of the implemented DAQ system while the data read is the basis for identification and automated configuration of the ionization chamber, in accordance with the well known and widely accepted PnP concept.

In addition to standard templates, smart sensor manufacturers may create and use their own templates. This approach covers the sensors not supported by the IEEE standard; some authors used the opportunity and proposed their own customized templates [13, 14]. In order to preserve the interoperability and enable PnP capability a new template for the ionization chamber, based on the 1451.4 property commands, is proposed and implemented in this paper, as will be described in the following section.

### PROPOSED ELECTRONIC DATA SHEET FOR IONIZATION CHAMBER

Electronic sensor specifications in the form of TEDS play key role when performing automatic network connection and configuration of a sensor in accordance with PnP concept. This section focuses on the systematization of the ionization chamber characteristics and standardization of TEDS information for this type of detector. Based on the latter analyses, TEDS template for the ionization chamber is proposed and designed.

For a standardized definition of the content of TEDS sections for the ionization chamber, one should be familiar with basic identification data, as well as with construction, electrical and measurement characteristics of the ionization chamber. Therefore, a short review of construction, electrical and measurement characteristics of the ionization chamber will be given below. Special attention will be paid to the air-equivalent dc current ionization chamber that is used in this study for the implementation of smart ionization chamber for a network connection.

Although ionization chambers have simple construction, and are certainly the simplest of all the gas-filled detectors, there are different types of ionization chambers. The following chamber types are commonly used depending on the construction: free-air chamber, vented chamber, sealed low pressure chamber, high pressure chamber, and research and calibration chamber.

Any fill gas can be used for the ionization chamber, but air is required in those chambers designed for the measurement of gamma-ray exposure. In addition to air, ionization chambers can be filled with nitrogen, argon, tissue equivalent gas, *etc.* The fill gas pressure is often 1 atm\*, although higher pressures are sometimes used in order to increase the sensitivity.

\* 1 atm = 101325 Pa

The ionization chambers vary greatly in dimensions and geometry to suit application. The electric field between plates is uniform with ionization chambers with parallel plate or planar technology. Ionization chambers with cylindrical geometry, where the field is inversely proportional to the radius, are frequently used as well. Analytical methods for prediction of current-voltage characteristics of chambers of various geometries are given in [15].

A change of temperature and/or pressure affects the air density and, consequently, a sensitivity of the ionization chamber. This implies that the environment parameters should be taken into account if a precise measurement is desired.

Measurable radiations with ionization chambers are X,  $\gamma$ , neutron, and  $\beta$ -ray. For detection of beta radiation, the ionization chambers with thin window that allows the penetration of beta particles into the detector are used. Beta particles are effectively prevented from being detected when the window is covered. The chamber wall must be thicker in ionization chambers with high pressure, disallowing detection of beta radiation as well as low energy gamma and X radiation (below approximately 40 keV).

Electrical characteristics of an ionization chamber comprise input power supply, operating voltage, maximum operating voltage, voltage plateau, mode of operation, current measurement range or range of electric charge, leakage current, and operating temperature range. The relation between applied high voltage and saturated ionization current for the same radiation source is important for a current ionization chamber. When an ionization chamber is in the ionization region, a slight increase of the applied voltage should result in a negligible change of the measured current.

Measurement characteristics of ionization chamber include the type of measurable radiation, energy range, measurement range, sensitivity to the measured radiation, energy response, angular dependence, *etc.*

The proposed TEDS template for ionization chambers consists of five fields: Template ID, General, Measurement, Electrical, and Calibration and miscellaneous (tab. 1). Template ID field is 8-bit integer number used for unique identification of the template. The General field provides most important mechanical characteristics of the ionization chamber such as: chamber type, fill gas, fill pressure, and effective volume.

Measurement field specifies the sensor measurement characteristics and defines physical to electrical mapping operation performed within the sensor. Depending on the construction specifications, ionization chambers can be designed to detect X, gamma, neutron or beta radiation. The first parameter in this field, Type of radiation, defines the type of radioactive sources that ionization chamber is sensitive to. It is possible to specify more than one type of radiation with corresponding list of parameters. In order to de-

fine the end of the Measurement field, the last parameter, Next type of radiation, must be set to the value No source.

Electrical field defines electrical characteristics of ionization chamber, electrometer amplifier, and power supply. Electrical characteristics of sensor output are specified using ionization chamber current output range and corresponding electrometer amplifier voltage output range. Specification of operational voltage for ionization chamber is provided with recommended and maximum high voltage supply parameters. Input power supply for smart ionization chamber is defined using Input power supply parameter.

Additional parameters are defined in Calibration and miscellaneous field. Calibration date is set as the number of days elapsed since 1st February 1998. Calibration period is used to warn the user if ionization chamber needs to be re-calibrated. Measurement location ID parameter serves as user-specified ionization chamber location ID.

Calibration data of each sensor can be stored in the TEDS memory using standardized templates: Calibration table or Calibration curve. Based on the calibration data, corrections of the measured physical quantity using corresponding electrical equivalent can be carried out.

Ionization chamber response depends on the radiation energy and incident angle of the radiation relative to the chamber axis. These dependences have an influence on the measurement results and therefore it is important to find a way to incorporate corrective data in the transducer TEDS memory. These corrections could be very efficiently stored in the calibration table. However, the standard IEEE 1451.4 templates do not provide a possibility to make corrections to the measured physical quantity based on an arbitrary domain parameter such as energy, angle of radiation, temperature, pressure or any other parameter which may be of interest. For this reason, a new Correction table template is proposed in this paper and shown in tab. 2.

Correction table template consists of three fields: Template ID, table header, and table entries. Template ID provides unique identification of the template. Table header field stores data about physical quantity that influences measurement. Domain name parameter provides string description and minimum domain value and maximum domain value define range of interest for the physical quantity. Number of entries parameter is used to specify size of the Correction table. Up to 127 entry points are allowed. Every table entry has two co-ordinates defined with domain value and correction factor value parameters. Using the correction table template, the energy and angular dependence of ionization chamber as well as corrections due to changes in pressure, temperature and other parameters can be written into TEDS.

**Table 1. Transducer TEDS template for gamma ray sensitive ionizing chamber**

Field	Data type and range
Template ID	8b, integer (0-255)
General field	
Chamber type	3b, enum: 0 = free-air, 1 = vented, 2 = low pressure, 3 = high pressure, 4 = research and calibration
Fill gas	30b, string
Fill pressure [mmHg]	16b, integer (0-65534)
Eff. volume [ 10 <sup>-1</sup> cm <sup>3</sup> ]	18b, integer (0-262142)
Measurement field for gamma radiation	
Type of radiation	3b, enum: 1 = beta, 2 = gamma, 3 = X, 4 = neutron, 0 = no source
Radiation	1b, enum: <sup>60</sup> Co, <sup>137</sup> Cs
Sensitivity [AC <sup>-1</sup> kgs]	32b, floating point
Min. exposure rate [Ckg <sup>-1</sup> s <sup>-1</sup> ]	32b, floating point
Max. exposure rate [Ckg <sup>-1</sup> s <sup>-1</sup> ]	32b, floating point
Next type of radiation	3b, enum: 1 = beta, 2 = gamma, 3 = X, 4 = neutron, 0 = no source
Electrical field	
Min. IC current out [A]	32b, floating point
Max. IC current out [A]	32b, floating point
Min. electrom. out [V]	10b, dec (0-10, step 10 <sup>-2</sup> )
Max. electrom. out [V]	10b, dec (0-10, step 10 <sup>-2</sup> )
Recom. HV supply [V]	9b, integer (0-5100, step 10)
Max. HV supply [V]	9b, integer (0-5100, step 10)
Input power supply [V]	9b, integer (0-51, step 0.1)
Calibration and miscellaneous field	
Calibration date	16b, integer (0-65534)
Calibration period [day]	22b, integer (0-4094)
Measurement location ID	11b, integer (0-2046)

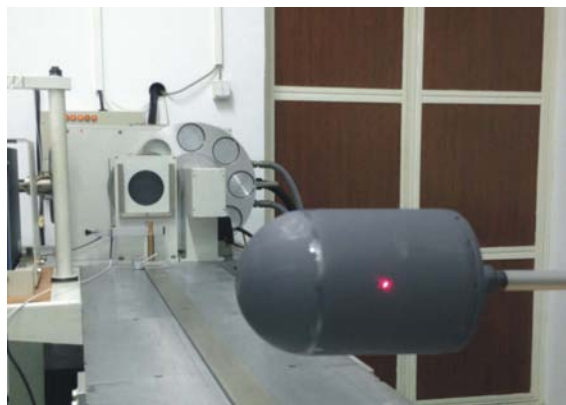
**Table 2. Correction table template**

Field	Data type and range
Template ID	8b, integer (0 to 255)
Table header	
Domain name	30b, string
Minimum domain value	32b, floating point
Maximum domain value	32b, floating point
Number of entries	7b, integer (0-127)
Table entries	
Domain value [%] <sup>a</sup>	14b, dec (0-100, step 10 <sup>-2</sup> )
Correction factor value <sup>a</sup>	21b, dec (0-21, step 10 <sup>-5</sup> )

<sup>a</sup> Repeated number of entries times

## TESTING OF SMART IONIZATION CHAMBER

The M1000 is an air-equivalent ionization chamber with volume of 1000 cm<sup>3</sup> and wall thickness of 2 mm (fig. 4). The inner surfaces of the chamber are



**Figure 4.** The ionization chamber M1000 under test with X-ray machine

coated with a conductive air-equivalent layer. Recommended operating voltage is 400 V.

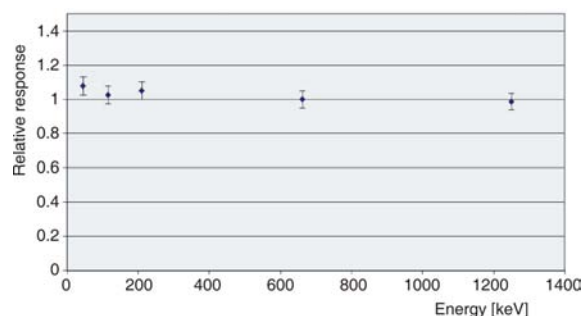
To evaluate the characteristics of ionization chamber, it was calibrated at the Laboratory for radiation measurements, Vinča Institute of Nuclear Science, Belgrade, Serbia. X-ray beam at effective energies of 46 keV, 114 keV, and 195 keV generated by Philips MG320 X-ray machine, and dosimetric gamma ray sources  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  were used for the calibration. The ionization current is measured using the Keithley 610 C electrometer with a relative error less than 3%. The total relative error of measurement is less than 5%. The ionization chamber response vs. energy is shown in fig. 5.

As can be seen from fig. 5, the energy response is relatively uniform in the range from 46 keV to the 1.25 MeV with a relative deviation within the 8%. Gamma ray sensitivity of the ionization chamber was tested with the collimated  $^{60}\text{Co}$  source. The chamber saturated current  $I_s$  as function of exposure rate is illustrated in fig. 6.

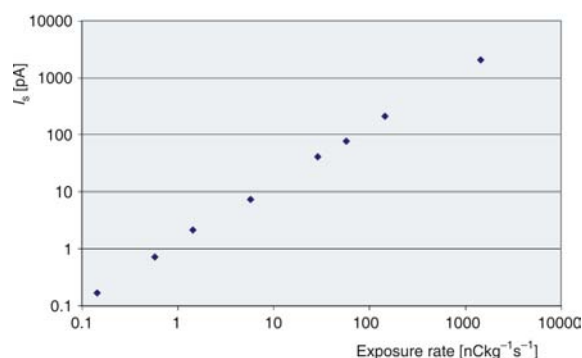
Based on the ionization chamber M1000 characteristics and our proposals for TEDS template for gamma radiation ionization chamber (tab. 1) and Corrections template (tab. 2), TEDS for smart ionization chamber has been designed according to the proposal which is presented in this paper.

For reading and writing of smart ionization chamber TEDS data in EEPROM memory, application software TEDS Editor is developed. TEDS Editor is a PC-based application developed in LabVIEW programming environment [16] applying the concept of virtual instrumentation. Graphical user interface of TEDS Editor is shown in fig. 7.

Basic sensor data are entered by selecting “Edit Basic TEDS” option from TEDS Editor front panel. Details about the mechanical, measurement, electrical, and additional characteristics of ionization chamber are entered by selecting “Edit Transducer TEDS” option. These data are stored in TEDS on the basis of the proposed Transducer template for ionization



**Figure 5.** The relative ionization chamber sensitivity as a function of X and gamma radiation energy



**Figure 6.** The M1000 ionization chamber saturated current vs. exposure rate

chamber presented in tab. 1. Ionization chamber energy response, shown in fig. 5, is entered in TEDS memory according to proposed Correction table template (tab. 2) using “Edit Correction TEDS” option from graphical user interface. Gamma ray sensitivity as a function of exposure rate, shown in fig. 6, is stored in TEDS memory using “Edit Calibration TEDS” option from graphical user interface. Sensitivity data are stored in TEDS according to IEEE 1451.4 standard Calibration template [9].

After creating TEDS table, the user may store data in “EEPROM memory” or “virtual TEDS” file by choosing appropriate “target location”. “EEPROM memory” option provides data transfer between TEDS Editor and TEDS EEPROM memory using IEEE 1451.4 compliant DAQ connected to the PC via USB bus. DAQ uses Mixed-mode interface and One-wire protocol for detecting presence of EEPROM memory and transfer of TEDS data. Alternatively, TEDS Editor allows user to read or write data to “virtual TEDS” file when EEPROM memory cannot be attached to the sensor.

To test smart ionization chamber and DAQ, which are designed and implemented within this work, LabVIEW client application is designed. As this program design is not the focus of this paper, it will be described only briefly.

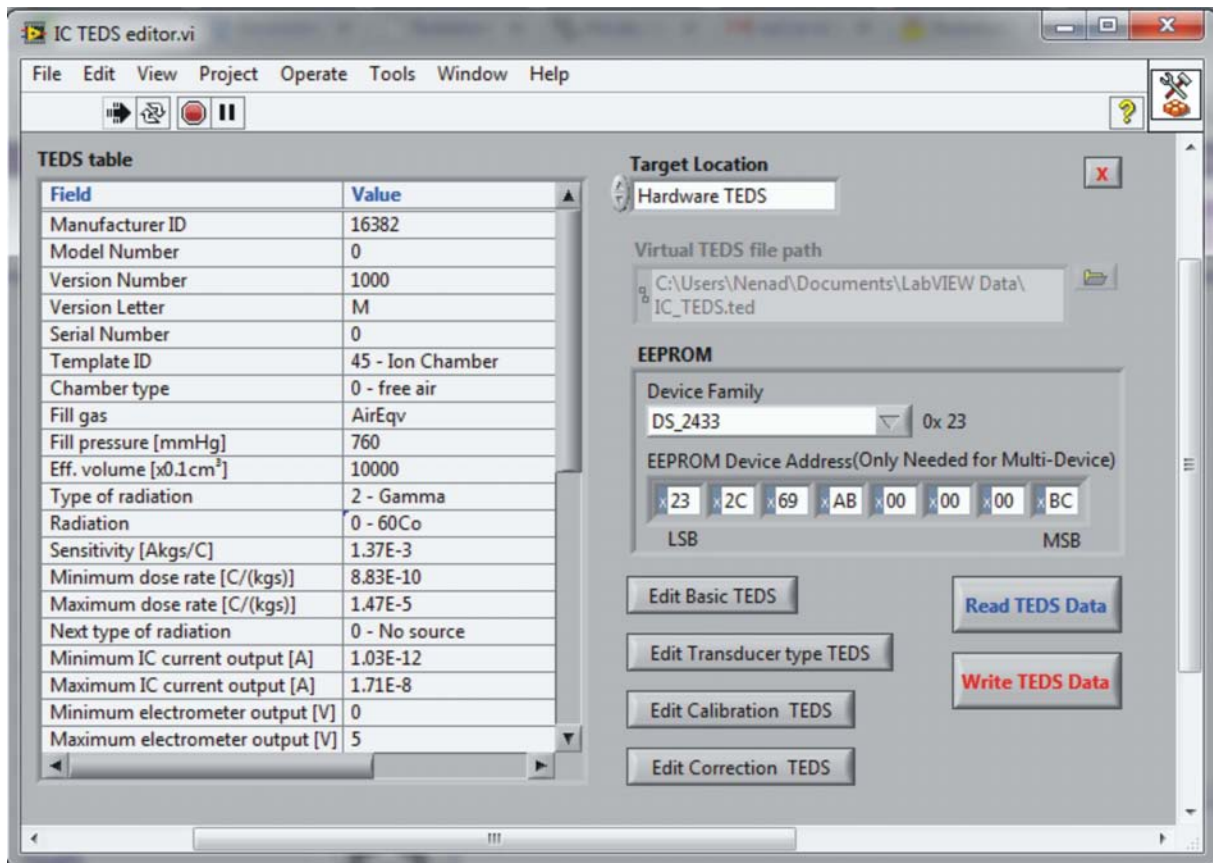


Figure 7. Front panel of TEDS editor for smart ionization chamber

The front panel of client application is shown in fig. 8. Client application allows a remote client to access the smart ionization chamber through the network. In these experiments a PC is used as a network capable application processor (NCAP). By choosing the appropriate sensor from the client application front panel, TCP/IP connection between client and NCAP is established, and TEDS data from the selected detector is obtained. In addition to basic information about the detector shown in graphical user interface (fig. 8), the user can request detailed TEDS data by selecting “View TEDS” option.

Based on the data regarding electrometer amplifier and the ionization chamber’s sensitivity specified in TEDS memory, NCAP automatically performs conversion from voltage measured at the amplifier output to appropriate exposure rate. The data obtained from the temperature and pressure sensor embedded in the ionization chamber are used for refining the measurement of exposure rate to ambient conditions. Further corrections of calculated exposure rate is performed using Correction table TEDS data. If either isotope or energy of ionizing radiation is known, these data can be entered through the graphical user interface of the client application. Based on these data and the data stored in the Correction TEDS, appropriate correction of the measurement result is performed. Similarly, if

the radiation incidence angle to the ionization chamber is known, then exposure rate value can be corrected based on the data stored in angular dependence Correction table section of TEDS memory.

After entering correction data and sensor configuration, client application periodically requests transfer of relevant measurement results and graphically displays or/and records obtained data, at the user’s convenience.

## CONCLUSIONS

This paper presented design and implementation of smart ionization chamber which can be connected to the monitoring network in accordance to the PnP concept.

In order to perform automatic network connection and configuration of the ionization chamber, an appropriate TEDS template containing all the relevant construction, electrical and measurement characteristics of the ionization chamber should be available. As this template is non-existent within IEEE 1451.4 standard, it was developed within this work. Also, a new correction table template for the correction of measurement results is proposed in this paper. Based on the calibration data stored in TEDS memory, correc-

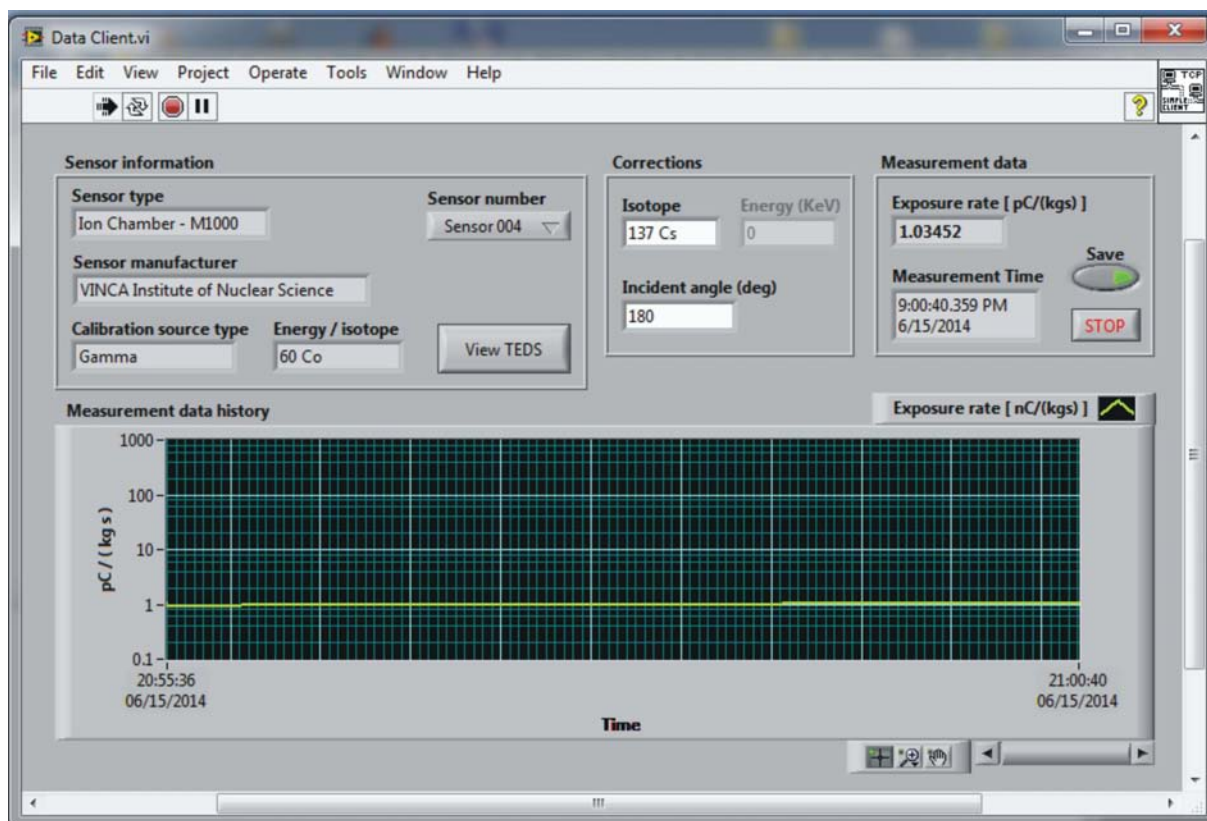


Figure 8. Graphical user interface of client application for remote access to the smart ionization chamber

tion of the measured physical quantity based on corresponding electrical equivalent is carried out.

IEEE 1451.4 compliant data acquisition system has been designed for interfacing of smart ionization chamber. The experimental set-up includes ionization chamber with an embedded EEPROM memory chip for data specifications, electrometer amplifier and associated electronics, and DAQ based on low-cost 8-bit microcontroller with Mixed-mode interface. Through the DAQ, the smart ionization chamber is connected to the PC for data processing and network communication.

The proposed system for PnP interfacing of smart ionization chamber has been tested with the air-equivalent 1 liter ionization chamber. The ionization chamber has been calibrated with X-ray beam and dosimetric gamma radiation sources  $^{137}\text{Cs}$  and  $^{60}\text{Co}$ . The data obtained by the calibration of the ionization chamber as well as construction and electrical characteristics of the ionization chamber have been written into TEDS memory associated to the ionization chamber. By means of the implemented DAQ system, the concept of automatic interfacing and configuration of an ionization chamber as well as a correction of the measured value based on the calibration data is demonstrated.

With the aim to test the smart ionization chamber and DAQ system, LabVIEW client application is de-

signed. As shown, the proposed smart ionization chamber can be accessed over the network and the user is provided with the measurement results and detailed information about connected radiation detector, detector location and measurement result.

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#### AUTHOR CONTRIBUTIONS

The research idea and the theoretical analysis were carried out by V. R. Drndarević. The design of interfacing electronics was carried out by N. J. Jevtić, V. R. Drndarević, and V. M. Rajović. Implementation of TEDS template for ionization chamber and design of TEDS Editor were performed by N. J. Jevtić. The manuscript was prepared jointly by V. R. Drndarević, N. J. Jevtić, and V. M. Rajović. The figures and tables were prepared by V. R. Drndarević and N. J. Jevtić. Validation experiments were prepared by V. R. Drndarević and S. J. Stanković and carried out by all authors. All authors analyzed and discussed the results.



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### ПАМЕТНА ЈОНИЗАЦИОНА КОМОРА ЗА МОНИТОРИНГ ГАМА ЗРАЧЕЊА

У овом раду описан је поступак пројектовања и реализације паметне јонизационе коморе погодне за повезивање у мрежу за мониторинг гама зрачења. Паметна јонизациона комора састоји се од ваздух-еквивалентне јонизационе коморе запремине један литар, пратеће електронике и уграђене меморије за памћење електронских спецификација јонизационе коморе. У уграђени меморијски чип уписане су основне, радне и мерне карактеристике коришћене јонизационе коморе. За читавање електронских спецификација јонизационе коморе из меморијског чипа и за конфигурирање и повезивање јонизационе коморе на мониторинг мрежу у складу са концептом прикључи и ради (*plug-and-play*), реализован је микроконтролерски аквизициони систем са стандардизованим мешовитим интерфејсом. У раду су дати детаљи реализације и резултати тестирања паметне јонизационе коморе.

*Кључне речи:* њамејан сензор, јонизациона комора, њовезивање, мрежа, IEEE 1451, TEDS