MEASURING CHANNEL OF ELECTRON RADIATION ABSORBED POWER

S.P. Karasyov, R.I. Pomatsalyuk, A.Eh. Tenishev, V.L. Uvarov
National Science Center "Kharkov Institute of Physics and Technology", 61108, Kharkov, Ukraine;
E-mail: uvarov@kipt.kharkov.ua

The measuring channel of absorbed power of the electron radiation in the range 0.1...100 kW using a flow-type calorimetric absorber is described in the paper. The measuring circuit of the channel performs determination of cooling liquid temperature at the input and output of the absorber and also makes measurement of the flow rate of a cooling liquid. The absorbed power is calculated from the measured parameters and then is displayed and stored into the channel memory. The measured and calculated parameters are transferred to the external computer by means of serial interface of RS-232 type. The measuring channel has been made as a stand-alone module with a LCD display and control keypad. The measurement process is carried out both in off-line mode, and under control of the external computer.

PACS: 06.60.Mr, 07.77.Ka

1. INTRODUCTION

"Accelerator" R & D Prod. Est. of NSC KIPT develops and operates high-current electron linacs. Their basic parameters under radiation - technological programs are as follows:

Energy of electrons, MeV	- up to 12
Beam power, kW	- up to 15
Beam scanning range (at the exit of window), cm	- up to 40.

The measuring channel for certification and calibration of accelerators by the energy flow (beam power) under conditions of a scanned beam has been designed. The calorimeter of a total absorption with an absorber of a special geometry providing a minimum of beam power dissipation is used.

2. DESIGN OF THE MEASURING CHANNEL

2.1. The measuring channel consists of the primary sensor (beam absorber) and the measuring circuit. The sensor under the plan of build-up corresponds to a calorimeter - Faraday cup. It provides a possibility of simultaneous measuring of power and average beam current so to estimate an average value of the electron energy.

The geometry of the sensor is given in Fig.1.

It comprises casing 1 and absorber 2. Running water cools the absorber through holes 3. The presence of ceramic insulators 4 in places of delivery and tap of water provides galvanic isolation of the absorber relatively to the grounded casing. Due to this the sensor also can be used as a free-air Faraday cup.

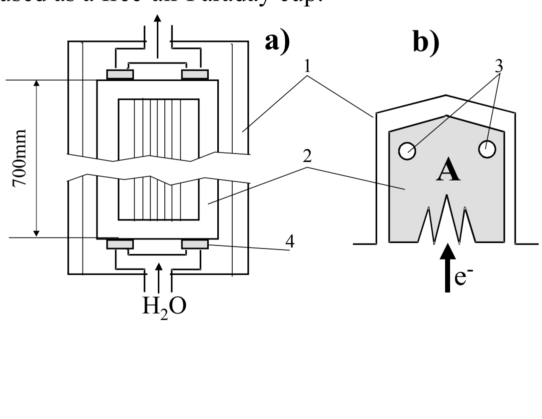

Fig. 1. The sensor: a - beam side view; b - section

The absorbed power P is determined by measuring the stationary difference of the water temperature (T2-T1) respectively at an output and inlet of the absorber under effect of the scanned electron beam with the water flow rate N using the expression

$$P = kC\rho\,(T2 - T1)\,N, \qquad (1)$$

where **C** - water heat capacity, ρ **-** water density, k – coefficient determined at metrology certification of the measuring channel.

2.2. Measuring channel functionally consists of the following modules (see Fig.2):

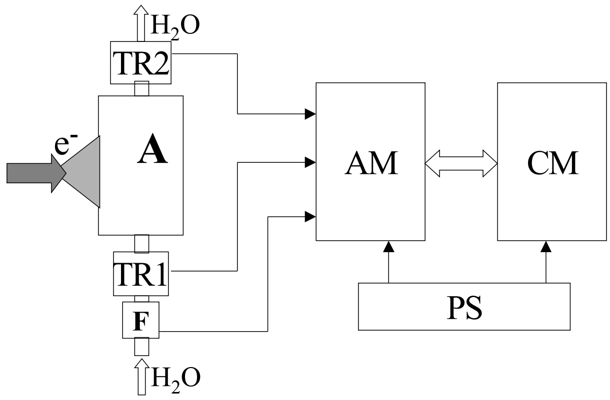

Fig. 2. The functional scheme of the measuring channel

- absorber A;
- module of analog signals measuring (AM);
- control module (CM);
- temperature sensors (thermoresistors T_1, T_2);
- flowmeter (F);
- power supply (PS).

3. COMPOSITION OF THE MEASURING CIRCUIT

3.1. The AM (Fig.3) consists of:
- 2 channels of voltage measuring;
- 2 direct current sources (CS);
- frequency measuring channel (FM);

PROBLEMS OF ATOMIC SIENCE AND TECHNOLOGY. 2004. № 1.
Series: Nuclear Physics Investigations (42), p.162-164.

- analog-to-digital converter (ADC);
- optoisolator (OI).

The main functions of the AM as follows:

- conversion of analog signals acting with measuring circuits to a digital code using an analog-to-digital converter;

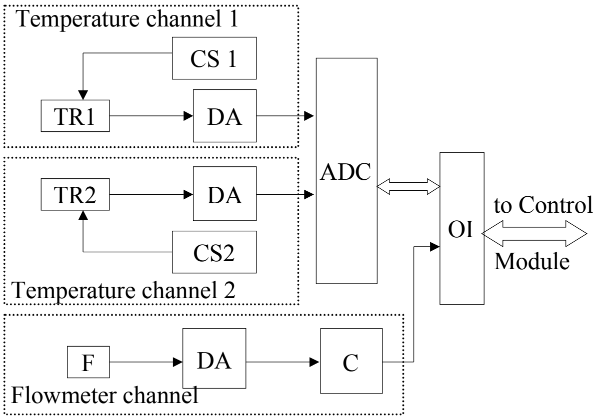

Fig. 3. The diagram of the analogy module

- feed of thermal probes by a direct current from a current source;
- conversion of a sine-wave signal from the flow meter in a sequence of digital pulses.

3.2. The control module (Fig.4) consists of:

- microcontroller (MC)
- peripheral data memory (RAM);
- programs memory (ROM);
- a display unit (LCD);
- control keypad (K);
- level translator of a serial interface RS-232(LT).

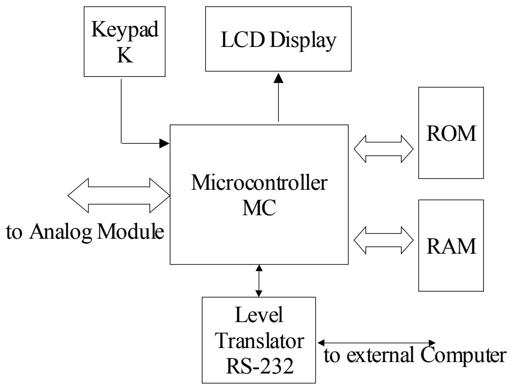

Fig. 4. The diagram of the control module

The main functions of the control module are:

- generation of control signals for operation ADC;
- accumulation of results of the measurement and conversion them into physical units;
- displaying of results on the LCD indicator;
- control of the device mode operation through control buttons on the front panel;
- data exchange with an external computer using serial interface RS-232.

3.3. The power supply unit generates the stabilized voltages +/-5 V for feed the AM and +5V for feed of the CM.

4. PROCEDURE OF TEMPERATURE MEASUREMENT AND CALCULATION

4.1. The platinum thermoresistors (TR) with the known transformation characteristic and calibration coefficients are used as temperature sensors.

The transformation characteristic of used TRs is described by expression

$$R=R_0\ (1+A\cdot t+B\cdot t^2), \qquad (2)$$

where R - resistance of TR at temperature t; R_0 - resistance of TR at temperature t=0°C; A, B - calibration coefficients for given TR.

The TR is connected to a measuring circuit using the four-wire scheme. Two conductors are used for exciting the TR by direct current of 300 μA from a direct current source, and two another are used to measure a drop of potential on TR. Such scheme of connection allows one to compensate completely a resistance of connecting wires, as TRs are placed on a sufficient distance (~50 м).

The voltage on TR is amplified by a differential amplifier (DA) and then converted to a digital code by ADC. Microcontroller reads out a digital code from an output of the ADC and performs necessary calculations.

The value of the voltage on TR is determined from expression

$$U=U_{ref}\cdot D\ /\ (2^n\cdot G), \qquad (3)$$

where D – is a digital code at the output of the ADC; U_{ref} – value of a reference voltage (V) on the ADC specifying a range of input voltages; 2^n - number of binary combinations for the ADC with the resolution of ***n*** bits; G – gain of the DA.

The D value is defined by averaging 100 ADC values. The conversion rate of ADC is selected to multiple frequency of a supply-line (50 Hz) and equals 100 Hz. At such ADC conversion rate and number of points the measurement time is 1 s.

4.2. The measuring of a temperature is performed by means of definition of the TR resistance and subsequent recalculation to temperature units with usage of calibration coefficients. The TR resistance is defined from the expression: $R=U/\ I_0$, where U is the measured voltage on TR with the known exciting current I_0.

For determination of the temperature the expression obtained from (2) is used

$$T = \pm\sqrt{\alpha^2 + \beta\cdot(r_0\cdot R - 1)} - \alpha\ , \qquad (4)$$

where R is the resistance of TR (Ω) at given temperature T(°C); α=A/2B, where A, B, R_0 from expression (2); β=1/B, $r_0=1/R_0$.

The sign before the root is defined by the sign of the coefficient B for T >0. If B<0, the sign before the root is negative.

5. MEASURING OF THE FLOW RATE

The industrial flow-rate unit of turbine TPR-10 type is used as a flow sensor of a cooling liquid.

The definition of the flow is performed by means of frequency measuring from an output of a flow sensor and recalculation it in units of the flow-rate (l/s). The

PROBLEMS OF ATOMIC SIENCE AND TECHNOLOGY. 2004. № 1.
Series: Nuclear Physics Investigations (42), p.162-164.

measuring circuit consists of a differential amplifier (DA) and comparator (C). From an output of a flow sensor the sine wave signal with a frequency of 100-1000 Hz and amplitude of 20…50 mV is amplified by DA and conversed in the comparator to a sequence of digital pulses with a frequency equal to the frequency of an input signal. In the control module the microcontroller measures the pulse repetition rate and converses it to units of the flow according to expression:

$$Q=F/B, \quad (5)$$

where Q is the flow rate a cooling liquid; F is the frequency from an output of a flow meter; B is the calibration coefficient.

6. OPERATION

The control of the operation mode and parameters settings of a measuring channel are carried out with the help of control buttons by selecting the corresponded menu items that are displayed on the LCD indicator.

The basic operation mode is a measurement of temperature T1 at the inlet and T2 at the outlet of the absorber and flow-rate Q of the cooling liquid. The measured values T1, T2, Q are displayed on the LCD indicator. Through a given time interval (1 s-10 min) they also are stored into the channel memory. The memory represents the nonvolatile SRAM with a feed from the lithium battery (the chip DS1225AB of Dallas Semiconductor is used), that allows to store the measured data during long period at a lack of the line-supply feed. Memory of the measuring channel allows to store up to 600 measured values of TR1, TR2, F. If necessary the stored data are transmitted to an external computer through the serial interface RS-232. From the beginning of a measurement the timer is started for counting of measuring time duration. The process of measuring is terminated on pressing the corresponded control button. Also there is an opportunity during measuring on requests from the external computer to transmit to it the current values of the measured quantities and assigned parameters.

All calibration coefficients for evaluations are stored in nonvolatile memory of the microcontroller. They are Assigned and changed via control buttons.

In the module of analog signals measuring the 12-bits ADC of AD7858 type (Analog Devices) is utilized. As differential amplifiers we used amplifiers of AD623 type of the same firm. The microcontroller of M68HC11E9 type (Motorola) is applied in the control module. The control software is written on the low-level language (Assembler) and allocates about 8kB of ROM.

CONCLUSION

As a result of the carried out development the measuring channel of electron radiation energy flow (power) with the following performances is designed and manufactured

- Power, kW - 0.1...100
- Temperature of cooling water, °C 0...100
- Flow rate of cooling water, l/s 0.12...0.60
- Range of electron beam scanning, cm up to 40
- Relative accuracy of absorbed power measuring, % no more than 3.

Also, the channel can be used for a continuous remote monitoring of an absorbed radiation power in target devices of charged particle accelerators.

REFERENCES

1. K.I. Antipov, M.I. Ayzatsky, Yu.I. Akchurin et al. Electron Linacs in the NSC KIPT: R&D and Application // *Problems of Atomic Science and Technology. Series: "Nuclear Physics Investigations" (37).* 2001, № 1, p. 40-47.
2. N.S. Shimanskaya. *Calorimetry of ionizing radiation. M.: "Atomizdat",* 1973, p. 328 (in Russian).

ИЗМЕРИТЕЛЬНЫЙ КАНАЛ ПОГЛОЩЕННОЙ МОЩНОСТИ ЭЛЕКТРОННОГО ИЗЛУЧЕНИЯ

С.П. Карасев, Р.И. Помацалюк, А.Э. Тенишев, В.Л. Уваров

Описан состав и принцип работы измерительного канала поглощенной мощности электронного излучения в диапазоне 0.1...100 кВт с использованием проточного калориметрического преобразователя. Измерительная цепь канала производит контроль температуры охлаждающей жидкости на входе и выходе преобразователя, а также измерение ее расхода. По этим параметрам производится определение поглощенной мощности электронного излучения с последующим ее отображением на дисплее и накоплением в памяти канала. При необходимости все контролируемые и вычисленные параметры передаются на внешнюю ЭВМ по последовательному интерфейсу RS-232. Измерительный канал выполнен в виде отдельного устройства с LCD-дисплеем и клавиатурой для управления. Это позволяет проводить измерения как в автономном режиме, так и под управлением ЭВМ.

ВИМІРЮВАЛЬНИЙ КАНАЛ ПОГЛИНЕНОЇ ПОТУЖНОСТІ ЕЛЕКТРОННОГО ВИПРОМІНЮВАННЯ

С.П. Карасьов, Р.І. Помацалюк, А.Е. Тєнішев, .В.Л. Уваров

Описані склад і принцип роботи вимірювального каналу поглиненої потужності електронного випромінювання в діапазоні 0.1...100 кВт із використанням проточного калориметричного перетворювача. Вимірювальний тракт каналу здійснює контроль температури охолоджувальної рідини на вході і виході перетворювача, а також вимірювання її витрати. По цих параметрах визначається поглинена потужність електронного випромінювання з подальшим її відображенням на дисплеї і накопиченням у пам'яті каналу. При необхідності всі контрольовані й обчислені параметри передаються на зовнішню ЕОМ по послідовному інтерфейсові RS-232. Вимірювальний канал виконано у вигляді окремого пристрою з LCD-дисплеєм і клавіатурою для керування. Це дозволяє проводити вимірювання як в автономному режимі, так і під керуванням ЕОМ.