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THERMOREGULATED NITRIC CRYOSYSTEM FOR COOLING GAS-FILLED DETECTORS OF IONIZING RADIATION

A cryosystem has been designed for cooling and filling the gas-filled detectors of ionizing radiation with compressed inert gas. It is based wide-mouthed nitrogen cryostat that enables controlling detector temperature in the range of 173 – 293 K and stabilizing it with accuracy of ± 1°. The project has been implemented within the Ukraine–NATO Program of Collaboration, Grant SfP no.984655.

Keywords: cryosystem, nitrogen, temperature control, temperature stability, and gas-filled radiation detectors.

Gas-filled detector is an ionization camera designed to measure the level of radiation. Usually, it is filled with an inert gas (or mixture with other gases). There are two types of gas-filled detectors: the current (integrating) type and the pulse one. In the latter case, the rapid electrons gather on the anode detector, while the slowly drifting heavy positive ions do not have enough time for reaching the cathode. This makes it possible to record individual pulses from each particle. In such detectors, the third electrode, the grid, is placed near the anode to shield it from the positive ions.

Such detectors can measure not only the alpha-, beta- or gamma radiation, but also the neutron radiation, which usually is problematic because the neutrons have no charge and do not ionize gas when passing through the detector. While measuring the neutron flux the detectors can operate in three modes: the pulse mode, when registering the low-intensive fluxes; the current mode, for recording of the high-intensive fluxes; and the fluctuation mode, in between the current and the pulse modes.

Cooling of the detector enables its filling with inert gas kept in the compressed state while heating up to ambient temperature. Compressed xenon (up to about 60 bar) has a unique combination of physical properties: high braking ability, low Fano factor, mechanical and chemical stability, and low energy needed to create electron-ion pairs. In addition, xenon is a relatively cheap material. All these factors make it very attractive as active medium of radiation detectors.

The xenon gamma spectrometers have undeniable advantages: radiation stability; linear characteristics; resistance to vibrations; thermal sta-

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Fig. 1. Cryosystem

bility; and timing stability. If 3—5 % 3He is added to the camera filled with xenon, it becomes a detector of thermal neutrons with 100% effective recording.

Today, there have been researches related to the design of small devices for effective cooling of photoelectronic receivers at temperatures close to the temperature of liquid nitrogen in order to reduce thermal noise and to improve the signal / noise ratio of infrared radiation photodetectors of different types [1—4].

Within the framework of NATO-Ukraine cooperation program, a cryosystem based on wide-mouthed nitrogen cryostat (Fig. 1) has been designed. It enables filling and controlling temperature inside gas-filled detectors within the range of 173—293 K, and stabilizing it with an accuracy of ± 1°.

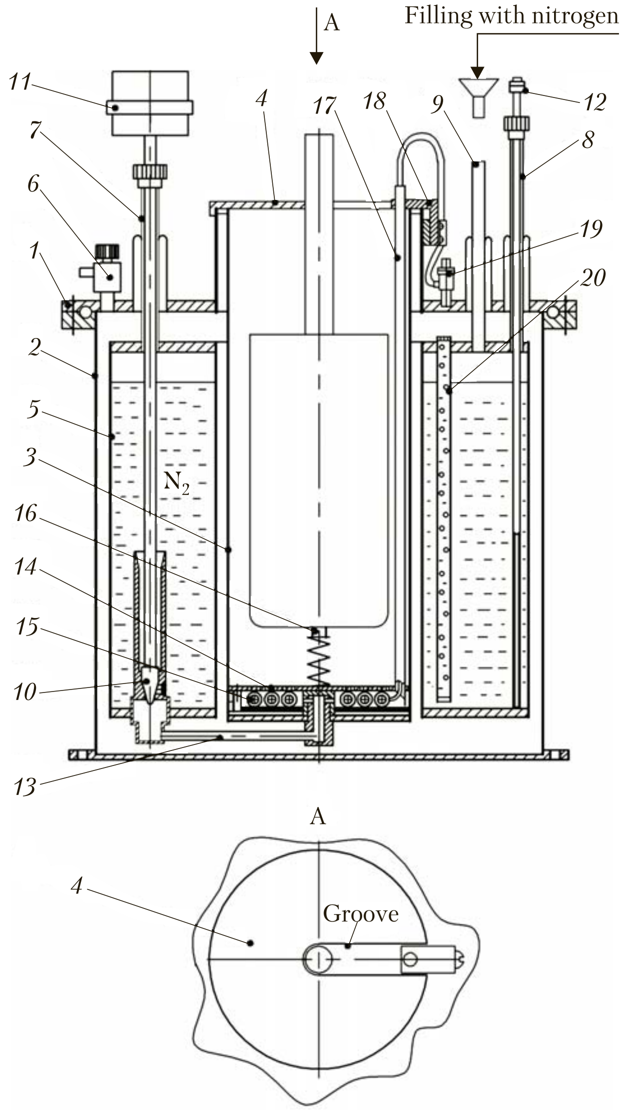

Fig. 2. Wide-mouthed nitrogen cryostat

The system consists of specially designed wide-mouthed nitrogen cryostat, temperature controller, and controlled elevator, which are integrated in a cryogenic complex. The nitrogen cryostat is schematically showed in Fig. 2; its structural and functional diagram is given in Fig. 3.

On the cover *1* of the external housing *2*, the shaft *3* is mounted with the shaft door *4*, and the nitrogen container *5*. The cover *1* bears also the vacuum valve *6* and the thin tubes *7*, *8*, and *9* connected to the nitrogen container *5*, which are

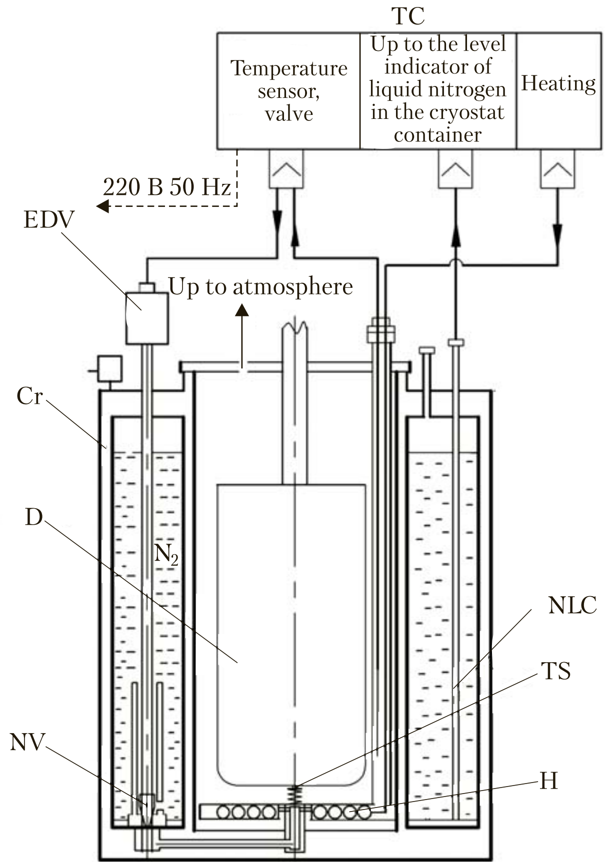

Fig. 3. Layout of thermally controlled nitrogen cryosystem: Cr – cryostat, D – detector, EDV – electro-dynamical valve, NV – needle valve, NLC – nitrogen level sensor, TS – temperature sensor, H – heater, TC – temperature controller

used for mounting the needle valve *10* with the control solenoid *11*, and the level indicator *12* and for pouring liquid nitrogen. The needle valve *10* regulates the supply of liquid nitrogen through the nitrogen feed line *13* into the shaft *3*. To ensure the required decrease (increase) in the temperature of detector or control camera placed in the shaft *3*, the electric heater *15* is mounted between the bottom of the shaft and the perforated sheet *14*. The heater is dual-purposed: firstly, it is designed for lowering the temperature and maintaining its set value due to switching on the current, for short periods, through the heater *15* evaporating liquid nitrogen into gas that through the perforated sheet *14* is fed evenly into the shaft *3* and cools the detector or the control camera; secondly, it is used for raising the temperature of heater *15* for heating the detector.

The spring-loaded temperature sensor 16 is pressed against the bottom of the detector to provide contact and sends a signal through the electronic module to the heater *15* and to the solenoid *11* for establishing and maintaining a required temperature. The electric wires from the heater *15* pass through the two tubes *17* mounted on the top part of the shaft using the bracket *18* and connected to the connector *19* on the cover *1*. The vacuum cavity of nitrogen cryostat is pumped out using a backing pump through the vacuum valve *6*. Hard vacuum is reached with the help of the cryopump *20* mounted in the nitrogen container.

The insert element with level indicator is showed in Fig. 4. It consists of two coaxial tubes: the outer *1* and the inner *2*. Each tube is connected to three wires unsoldered to the connector contacts *4* on the upper end of the tube *1*. The operation of level indicator is based on electrical capacitance of the sensor varying depending on the level of nitrogen in the container and, respec-

Difference of temperature between the operating and the control sensors

Preset temperature, °C	Actual temperature, °C	Temperature of reference sensor, °C	ΔT, °C
+20	+20	+18.6	1.4
+10	+10.5	+12.3	1.8
0	–0.4	3.3	3.7
–20	–20.1	–19.3	0.8
–30	–30.3	–25.5	4.8
–40	–40.5	–34.0	6.5
–50	–50.1	–43.4	6.7
–60	–60.3	–53.4	6.9
–70	–70.5	–63.5	7.0
–80	–81.0	–73.	7.0
–90	–94	–88.0	6.0
–100	–98.4	–92.6	5.8
–110	–109.2	–102.2	7.0

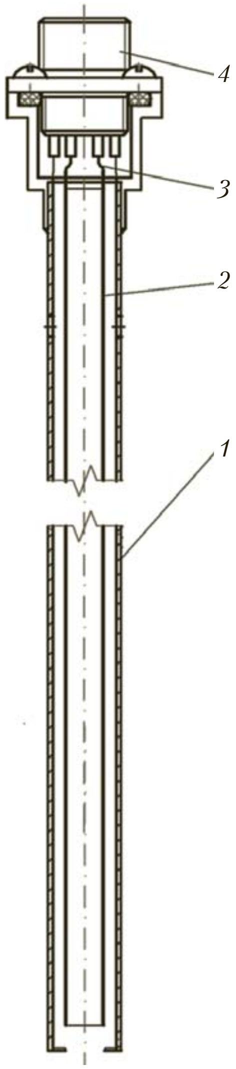

Fig. 4. Nitrogen level sensor

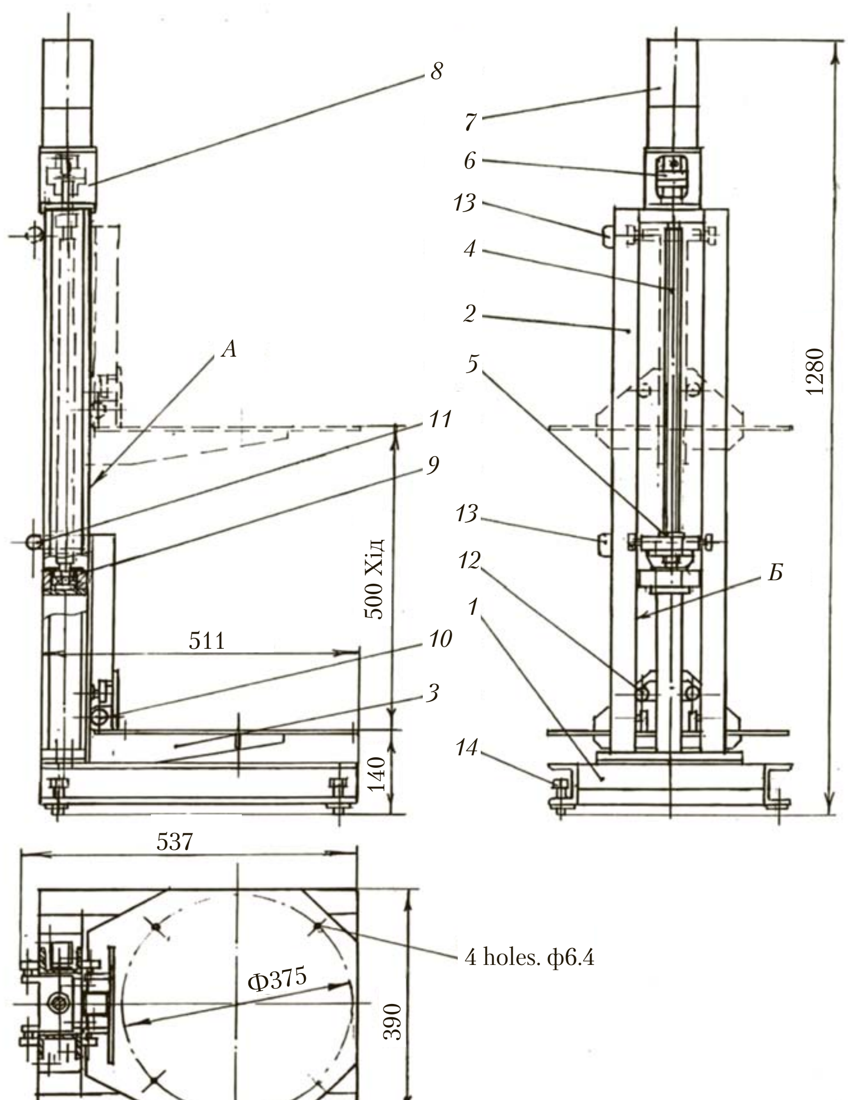

Fig. 5. Elevator of the nitrogen cryostat

tively, on varying frequency of the generator electrically coupled to the level sensor.

Sealing along the outer diameter of level sensor is ensured by clamping the nut of cryostat sealer, when installing the sensor into the cryostat.

Since the detector is mounted in the gas supply and pressure control system located in the camera that is an immobile structure consisting of a container with an inert gas, a gear, a set of tubes feeding the gas into the camera, a pressure gauge, and a relief valve and is fixed at a given height, it is necessary to design and to make an elevator for lifting the cryostat to required height in order to introduce the camera into the cryostat without damaging the gas supply system. The lifting mechanism is designed as showed in Fig. 5.

The elevator ensures lifting (lowering) the nitrogen cryostat for putting the detector or the control camera in (out) the shaft and consists of the frame *1*, the riser *2*, the table *3*, the screw *4*, the nut *5*, the coupling *6*, and the gear motor *7* installed on the riser *2* using the flange adaptor *8*. The screw *4* is mounted in the riser *2* and can rotate with the help of the gear motor *7* in the bearing unit *9*. The nut *5* is rigidly fixed to the table *3* having the support rollers *10, 11* and the rollers *12* that hold the table against lateral shift and enable its slide along the risers *2*. To control smooth rotation of the screw *4* relative to the nut *5* and smooth slide of table *3* along the risers *2*, the rollers *10, 11*, and *12* are mounted on eccentric axes with adjustable gap (up to 0.3 mm) between the rollers and the risers *2*. The frame 1 has the screws *14* for on-site adjustment of the lifting mechanism. There are four mounting holes for fastening the nitrogen cryostat on the surface of the table *3*. To turn off the electric drive, in the extreme positions of the table *3* there are the limit switches *13* installed on the riser *2* with adjustable time of their operation and slide of the table *3*. The electric drive is supplied with power from R5-150-24 DC source (U = 24 V, I = 6.5 A).

The cryosystem operates in the following way. The system is installed in accordance with the functional diagram. The nitrogen cryostat is mounted and fixed to the lifting mechanism coaxially with the detector. The cap *4* is dismantled from the shaft *3* and the cryostat is filled with liquid nitrogen. Temperature T = 293 K (20 °C) is set inside the shaft. The detector is loaded into the cryostat shaft by switching on the electric drive and lifting the cryostat to the top position. The detector's lower end face should press the spring-loaded sensor *16* located in the center of perforated sheet *14*. The cap *4* is set by pulling it to the central tube where the detector is fixed and then descends along the shaft *3*.

To cool the detector, the solenoid controls the needle valve for ensuring dosed supply of liquid nitrogen to the cryostat shaft through the heater that vaporizes liquid nitrogen and enables cooling with a required rate down to 173 K. This temperature is maintained for the time required for a given technological regime. The spent nitrogen gas is released to the atmosphere from the shaft through holes in the shaft cap. Having been kept at T = 173 K for the time required by a given technological regime, the liquid nitrogen into ceases to be fed to the shaft and the heater is triggered on to heat the detector.

To ensure the necessary rate of detector heating the heater may periodically switch off and on. Since the detector has a significant weight (10 kg) and heat capacity in terms of influencing the process of regulation, the temperature gradient decreases by stepwise regulation of temperature and its stabilization at a certain level required for uniform temperature distribution throughout the volume. To determine the temperature gradient, it was measured using a sensor that is in good thermal contact with the bottom of the detector and the control sensor fixed on the side wall of the detector, 10 cm from the bottom of the detector. The temperature gradient measured at a scanning speed of 20 degrees per hour show (see Table) does not exceed 7°. The system is showed in Fig. 5

As a result of research, the following results have been obtained:

Technical Parameters of Nitrogen Cryosystem

Cryoagent	liquid nitrogen
Range of temperature control, К,	173—293
Cooling rate, from 293 down to 173 К	від 293 до 173 К up to 20 K/hour
Keeping at a temperature of 173 К	during 3 hours
Heating rate, from 173 K to 293 К	173—293 up to 20 K/hour
Capacity of nitrogen tank, l,	17.5
Time of nonstop operation while temperature is falling down to 173 К without refilling the nitrogen tank, hours,	up to 18
Diameter of cryostat shaft, mm,	178
Length of cryostat shaft, mm	410

Dimensions of the Cryostat

Diameter, mm,	390
Height, mm,	610
Weight, kg,	50

Electric Heater in the Cryostat Shaft

Resistance, ohm	10
Material nichrome, Ø 0.7	L = 3000 mm
Voltage, V,	40

Technical parameters of the elevating system

Vertical travel, mm	500
Height of the table with respect to the floor, in the bottom position, mm	140
Bearing capacity, кГс,	60
Table elevator drive gear	electromechanical;
Dimensions, mm,	390 × 537 × 1280
Weight, kg,	50

CONCLUSIONS

The cryosystem ensures the control of detector's temperature within the range from 173 to 293 K and its stabilization with an accuracy of ± 1 °C. The elevating system enables introducing the camera to the cryostat without changing the camera position in the system for inert gas supply.

REFERENCES

1. Skubenko M.A., Zharkov I.P., Zhyrko Ju.I., Safronov V.V. *Minikriostatna systema MK-80 dlja zmenshennja temnovyh shumiv fotoelektronnyh pidsyljuvachiv*. Mater. UII Mizhnarodnoi' shkoly-koferencii' Aktual'ni problemy fizyky napivprovidnykiv. Drogobych, DPU, 28.09. 01.10.2010: 229—230 [in Ukrainian].
2. Zharkov Y.P., Zhyrko Ju.Y., Maslov V.A. ta in. Malogabarytnoe ustrojstvo ohlazhdenyja fotoelektronnyh umnozhytelej. *Nauchnoe pryborostroenye*. 2011. 21(1): 120—124 [in Ukrainian].
3. *Pat. Ukrai'ny N56983* Kriostat dlja fotoelektronnyh pidsyljuvachiv MPK G05D 23/30 / Zharkov I.P., V.O Maslov, V.O. Hodunov, A.G. Chmul' [in Ukrainian].
4. *Pat. Ukrai'ny N797425* Termoregul'ovanyj azotnyj kriostat dlja fotoelektronnyh pryjmachiv riznogo typu MPK G05D23/00 / Zharkov I.P., Safronov V.V., Selivanov O.V., Hodunov V.O [in Ukrainian].

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АЗОТНА КРІОСИСТЕМА З РЕГУЛЮВАННЯМ ТЕМПЕРАТУРИ ДЛЯ ОХОЛОДЖЕННЯ ГАЗОНАПОВНЕНИХ ДЕТЕКТОРІВ ІОНІЗУЮЧОГО ВИПРОМІНЮВАННЯ

Для охолодження та заповнення газонаповнених детекторів іонізуючого випромінювання стисненим інертним газом на базі широкогорлого азотного кріостату створена кріосистема, що забезпечує регулювання температури детектора в діапазоні 173—293 К і її стабілізацію з точністю ± 1°. Робота виконана в рамках Програми співробітництва Україна—НАТО, грант. SfP #984655.

Ключові слова: кріосистема, азот, терморегуляція, стабільність температури, газонаповнені детектори іонізуючого випромінювання.

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АЗОТНАЯ КРИОСИСТЕМА С РЕГУЛИРОВАНИЕМ ТЕМПЕРАТУРЫ ДЛЯ ОХЛАЖДЕНИЯ ГАЗОНАПОЛНЕННЫХ ДЕТЕКТОРОВ ИОНИЗИРУЮЩЕГО ИЗЛУЧЕНИЯ

Для охлаждения и заполнения газонаполненных детекторов ионизирующего излучения сжатым инертным газом на базе широкогорлого азотного криостата создана криосистема, обеспечивающая регулирование температуры детектора в диапазоне 173—293 К и ее стабилизацию с точностью ± 1°. Робота выполнена в рамках Программы сотрудничества Украина—НАТО, грант. SfP #984655.

Ключевые слова: криосистема, азот, терморегулирование, стабильность температуры, газонаполненные детекторы ионизирующего излучения.

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