

THE MAGNETIC FIELD MONITORING OF THE COMBAS SEPARATOR UNDER RADIATION CONDITIONS

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Abstract

In modern physical set-ups, such as accelerators and particle detectors, the magnetic field monitoring under real conditions of the experiment is of great importance. As a rule, the conditions of modern experiments (ATLAS, CMS, ALICE, LHC-B, STAR) put forward requirements to radiation hardness of the magnetometric apparatus used in the given set-up. At the Joint Institute for Nuclear Research (JINR) and State University «Lviv Polytechnic» (SULP) the apparatus is designed and tested for the magnetic field monitoring under radiation conditions. Hall Generators (HG) specially developed at SULP are used for these purposes as well as magnetic calibration stands designed and manufactured at the Laboratory of Particle Physics (LPP, JINR), the IBR-2 reactor (JINR), accelerator U400M and separator COMBAS at the Laboratory of Nuclear Reactions (LNR, JINR).

1 BLOCK-SCHEME OF THE EXPERIMENT

Testing of the prototype of the magnetometric apparatus for the monitoring of the magnetic field under radiation conditions [1] was carried out by the separator COMBAS at the accelerator U-400M (LNR, JINR) [2] (Fig.1).

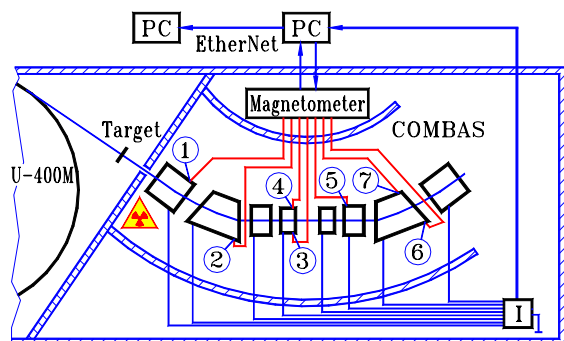


Figure 1: Block-scheme of the experiment

Wide aperture kinematic separator COMBAS was realized on the strong focusing principle. Magneto – optical system of the separator consists of 8 magnets with a complicated configuration of the working magnetic field and the level up to $B = 1.7$ T. [3]. The beam was transported via the channel from the accelerator U400M to the target. Further the products of the reaction were analyzed on the separator. For efficient transportation of the beam and the following stabilization regimes of the experiment to study ^{18}O , the data of the magnetic field monitoring were used. The sensors of the magnetic fields

were placed in the gap of the magnets at a close distance from the vacuum chamber with the beam of the particles under consideration. The measuring devices were located behind the radiation shielding in 10 metres.

2 MEASURING DEVICES

The magnetic field monitoring was performed by an 8-channel magnetometer in the real time regime (Fig.2).

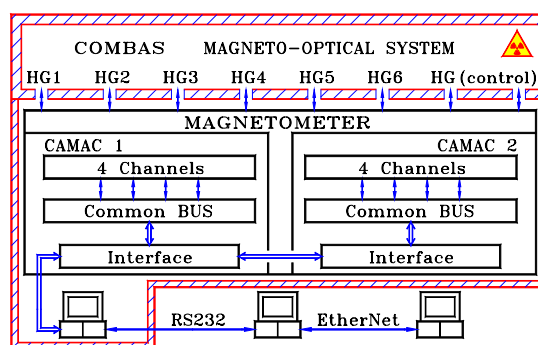


Figure 2: Block-scheme of the measuring devices

The control of the measuring devices and preliminary data processing were carried out by a computer in the experimental hall. Simultaneously the data were transferred to the central computer station to the control desk of the experiment on line RS232 and further to the EtherNet. Here the data of the magnetic field monitoring were compared with the measuring data of the radiation field and the working regimes of the separator (measurements of the current and field of the magnets). As sensors of the magnetic field were used 6 devices manufactured on a specialized technology of radiation resistive HG (SULP, Lviv) [4] and 2 industrial HG of type HG605 (St-Petersburg). The latter 2 were used as control sensors. During the experiment the 6 main HG and 1 control HG were placed in the gaps of the magnets under radiation conditions. The second control HG was not irradiated but used as a reference HG on the calibration stand. All the HG were thermostabilized at $t = +25$ °C ± 0.2 °. Before and after the experiment the apparatus was calibrated at the magnetic calibration stand [5] in the reference magnetic field. As a reference measurer of the magnetic field we have used the NMR magnetometer of the type PT2025 (METROLAB), which provided the absolute precision of measurements of the magnetic field in the uniformal area of the magnet gap ($\varnothing = 0.05$ m, gap = 0.03 m) – 0.001 %. On the results of the calibration the relative precision of the measurements of the magnetic

field for the main 6 measuring channels was 0.05 %, and for the control ones – 0.02 %.

3 EXPERIMENTAL DATA

3.1 Monitoring of the radiation field

In the location of the magnetic field sensors there were groups of detectors which measured the integral radiation values during the experiment for each of the 7 sensors. The experiment lasted 104 hours. To measure the values of gamma-rays and neutron fluences with the mean energy of $\langle E \rangle = 0.4.3$ MeV we have used the double dosimetry on the basis of thermoluminescent detectors LiF TLD-600 and LiF TLD-700 made by Harshaw company [6]. Before the experiment all the detectors were treated by thermal annealing. Detectors TLD-600 and TLD-700 were graduated in the gamma – radiation area of ^{60}Co at the standard graduation device to calculate the graduation coefficients. Additionally detectors TLD-600 were graduated in the field of neutron radiation of $^{239}\text{Pu}+\text{Be}$ in the free geometry at a distance of 1 m from the centre of the source [7]. Measurements of the detectors irradiated during the experiment were carried out by the device made by Harshaw company, model 2000(A+B). The results of measuring gamma-rays and neutron fluences with the energy of $\langle E \rangle = 0.4.3$ MeV in the experimental points are shown in Table 1.

Table 1: Results of the radiation field monitoring in the experimental points

# Irradiation Points	Gamma Rays luence (g/m2)	Neutron Fluence (n/m2)	
		0 - 4.3 MeV	4.3 - 10 MeV
1(control HG)	3.2×10^9	6.0×10^{14}	1.1×10^{16}
2 (basic HG #3)	2.1×10^8	2.6×10^{13}	1.6×10^{15}
3 (basic HG #1)	2.6×10^7	2.1×10^{13}	9.9×10^{13}
4 (basic HG #2)	7.6×10^7	5.2×10^{13}	3.8×10^{14}
5 (basic HG #5)	1.1×10^7	9.3×10^{12}	5.5×10^{13}
6 (basic HG #4)	2.4×10^7	8.0×10^{12}	9.6×10^{13}
7 (basic HG #6)	2.7×10^7	6.8×10^{12}	9.6×10^{13}

To measure the fluence of neutrons with the mean energy of $\langle E \rangle = 4.3-10$ MeV, we have used a standard activation method of threshold detectors [8]. Monitors made of Ni and Ti, which are a natural mixture of isotopes were purposed for this activity. For testing the used monitors and norming of the obtained results to the neutron spectrum close to the fission spectrum, the probe monitors Ni were exposed at the set-up «REGATA» of the IBR-2 reactor (LNP, JINR) [8] up to the fluence $F = 10^{19}$ n/m² for fast neutrons with $\langle E \rangle = 0.1-25$ MeV. The results of measurements of neutron fluences with $\langle E \rangle = 4.3 \pm 10$ MeV in the experimental points are shown in Table 1.

3.2 Magnetic field monitoring

Of about 3×10^5 values of the magnetic field in the real time regime have been measured and processed in each

of the experimental points during the experiment. The identity of different working regimes of the separator were guaranteed by the results of preliminary measurements of the detailed map of the magnetic field with the fixation of the regimes on the magnetic field and current in the control points of the magnets with the relative precision of – 0.02 % [3]. While repeating the working regimes of the separator on the supply current of the magnets and the magnetic field, the results of the magnetic field monitoring were compared in the experimental points on the dependence of time at the accumulation of the radiation dose by the magnetic field sensors.

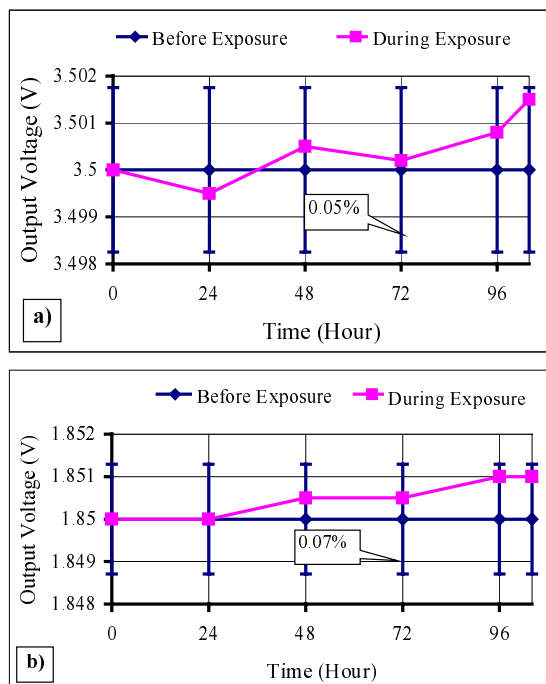


Figure 3: Dependence of the output voltage of HG on time in the irradiation process: a) HG6 in the magnetic field $B=1.45$ T; b) HG3 in the magnetic field of $B=0.8$ T

Figures 3a) and 3b) show the sensitivity change of the main measuring HG at the minimal (HG6) and maximal (HG3) radiation doses. It is seen from the drafts that at the lowest radiation dose HG6 has changed by 0.05 % from the initial value. At the maximal dose (at the end of the experiment) the change of the sensitivity for HG3 was 0.07 % of the initial value. Figure 4 shows the draft of

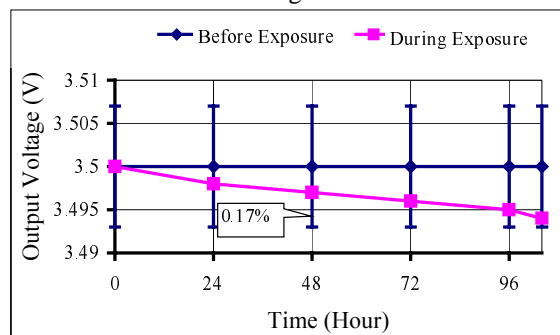


Figure 4: Dependence of the output voltage of the control HG on time in the process of radiation

sensitivity changes of the control HG at the accumulation of the radiation dose in the magnetic field $B=1.5$ T. At the end of the experiment (for the maximal dose) the sensitivity change of the control HG was 0.17 % of the initial value.

The data of the magnetic field monitoring have shown that the radiation resistive HG manufactured on a specialized technology have changed their sensitivity by 0.05-0.07 % during the experiment. At the same time the irradiated control HG has changed its sensitivity by 0.17 %.

After the experiment the apparatus was calibrated again on the magnetic calibration stand. Figures 5a) and 5b) illustrate the calibration curves for the main measuring HG at the minimal (HG6) and maximal (HG3) radiation dose.

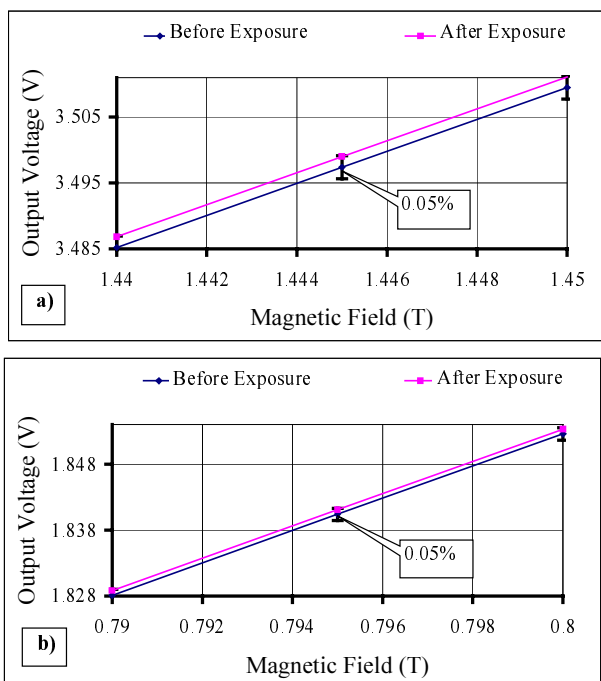


Figure 5: Dependence of the output voltage of HG on the magnetic field value before and after exposure: a) HG6; b) HG3

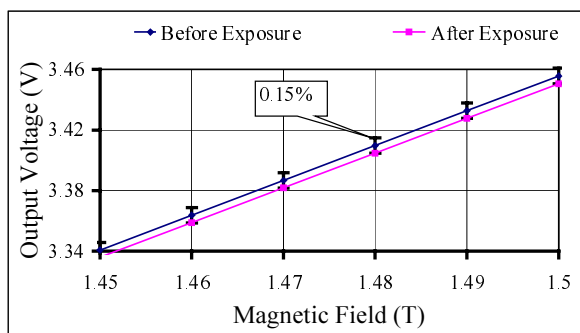


Figure 6: Dependence of the output voltage of the control HG on the magnetic field value before and after exposure

The calibration curves for the irradiated control HG before and after exposure are given in Figure 6.

The calibration data have shown that the radiation resistive HG manufactured on the specialized technology have changed their sensitivity on the average by 0.05 % during the experiment. At the same time the irradiated control HG has changed its sensitivity by 0.15 % but the unirradiated control HG has not changed its sensitivity (in the limits of the relative precision of the calibration – 0.02 %).

4 CONCLUSION

The experiment on the magnetic field monitoring under radiation conditions has been carried out at the accelerator U400M by the separator COMBAS (LNR, JINR). During the experiment in different experimental points the gamma-rays fluence was $\sim 1.1 \times 10^7 - 3.2 \times 10^9$ g/m² and the neutron fluence with the mean energy of $\langle E \rangle = 0-10$ MeV was $\sim 6.43 \times 10^{13} - 1.16 \times 10^{16}$ n/m².

The summed up relative precision of the magnetic field monitoring at the maximal radiation dose was:

1. For the industrial HG of type HG605 (St.-Petersburg) – 0.17 %.
2. For the radiation resistive HG manufactured on a specialized technology (SULP, Lviv) – 0.07 %.

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