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AUTOMATIC PRECISE FIELD MEASUREMENTS IN MAGNETS OF THE IHEP ACCELERATOR

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ABSTRACT

Numerosity and diversity of accelerator magnets as well as numerosity of primary measurement data have necessitated development of an automatic measuring system. This system provides for measurements both of local and integrated fields by local probes whose output is processed to take a digital punch-card form. Card data are then processed by a computer to obtain a final result of measurement.

The system was used for series calibration measurements of the circular magnet packages, for measurements of typical characteristics of these packages, and measurements of fringe fields in straight sections of the circular magnet.

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INTRODUCTION

The Serpukhov accelerator, and other high-energy proton synchrotrons, include several types of magnetic system for proton acceleration, particle beam separation to the physical experimental equipment, and for the execution of the experiment itself. Single electromagnets form the basis for such physical instruments as spark spectrometers and bubble chambers. Accelerator magnetic systems normally comprise a large number of identical electromagnets. The magnetic performance of the individual electromagnets in the system must be synchronized to 0.1% precision. Knowledge of the field topography in the working area of the gaps between the physical instruments' electromagnets should be accurate to a similar degree.

A magnetic system with a specific performance cannot be produced by the present methods for constructing and adapting electromagnets without carrying out precise measurements of each individual electromagnet's performance. The extremely accurate measurements required for the various field parameters of the electromagnet, the numerosity of electromagnets (600) and the large gaps between the physical instruments' electromagnets ($\sim 6\ m^3$) necessitate the processing of a large amount of primary information. Magnetic field detectors come in various types, including induction coils, permalloy detectors, detectors based on electronic paramagnetic resonance, Kholla detectors, ferrite generating detectors, etc. Table 1 includes information illustrating the amount of primary information acquired by measurements. With such a large amount of information, reliable measurements can only be transmitted promptly by automating both the actual measurements and also the processing of the primary measurement results.

A system has been developed, ensuring the automatic measurement of static and dynamic magnetic fields by means of various detectors[1]. All the primary measurement information is converted into a digital code and automatically punched on to standard cards which are then processed on a digital computer by means of a specially compiled program. A block diagram of the automatic measurement system is shown in Fig. 1.

The apparatus consists of functional blocks, thus providing an equivalent circuit for each type of measurement. The measurement assembly includes a coordinate apparatus, three punches, a reproducer and 13 cabinets containing electronic apparatus. A general view of the measurement apparatus is shown in Fig. 2. The automatic measuring apparatus was used for magnetic measurements in the IHEP magnet stand, for measuring the field index of the block packs, and also for studying the field topography of the blocks in the assembled electromagnet. Preparations are now being completed for an automatic measurement apparatus for spectrometric magnets.

As regards the performance of the automatic apparatus, Table 2 contains information on the separate elements in the assembly.

1. A STUDY OF THE MAGNETIC PERFORMANCE OF AN ACCELERATOR'S ELECTROMAGNET[2]

Research into the magnetic performance of the pack sections in an accelerator's electromagnet was carried out on the IHEP magnet stand between June and December of 1965.

Two measuring blocks and one control block were installed on the stand (Fig. 3). A special bracket fixed to one of the precision machine's supports facilitated both the installation of detectors in the gap of the measured pack to within an accuracy of ±50 microns in radius and height and also their movement in the equilibrium orbit area. Permalloy pick-ups were used as magnetic field detectors at 76 oersted injection levels and induction coils were used for medium and large fields. The measured pack contains two detectors equidistantly placed from the equilibrium orbit, thus enabling field and gradient values in the equilibrium orbit area to be calculated from measured field values at two points; detectors were installed in the control pack to conduct the relevant measurements.

Block magnetization was carried out by a cyclic method with parameters close to the specified rating.

Measurement results were collected during two consecutive magnetizing cycles. The information received was stored in two memory registers and transferred to standard punch-cards before the detectors were moved to the next point. Auxiliary information was also recorded on the punch cards (point coordinates, magnetization current of the permalloy detectors, operator code, pack number and date). Synchronization of the work of the measurement apparatus with the magnetization cycle was achieved by means of a multichannel timer. The root-mean-square error in measurements by the permalloy channel is $\pm 1.5 \times 10^{-4}$, and by the integrator channel $\pm 1 \times 10^{-4}$. The apparatus ensures a 90-minute calibration for one pack. The diagram shown in Fig. 4 represents pack distribution according to the size of the corresponding performance deviation from the mean value.

2. A TOPOGRAPHIC STUDY OF THE OPEN AND CLOSED BLOCKS IN AN ASSEMBLED ELECTROMAGNET[3)]

To acquire information for the design of proton and secondary particle extraction systems, a topographic study was made of the dynamic vertical component of magnetic field H_z in the median phase of blocks and straight-line gaps. Field pattern was studied in the electromagnet's open and closed blocks with the following equilibrium orbit field values - 6320, 8290, 10450, 11310 and 12650 oersted. The range of radius calculations extended from the internal areas where the field was 0.1 H_{z0}, to the external areas where the field was equivalent in size to 10^{-3} H_{z0} (H_{z0} being the vertical component of a field in equilibrium orbit). The block diagram of the apparatus used for these measurements appears in Fig. 5. Field value measurement at each point was made by means of a multiturn coil with an effective area of 4.2 m^2. Voltage on the coil was integrated by a precise integrator, the drift of which did not exceed 3 microvolts at input. The integrator's output voltage was measured by means of a fast-response digital voltmeter controlled by the magnetic field comparator and was then recorded in the memory register. To improve the accuracy of the results, measurements were made during two consecutive magnetization cycles. After the measurements were completed, the data from the registers was recorded on a standard punch-card.

With the automatic measurement apparatus which has been developed, a more precise assessment can be made of the magnetic performance of a large number of packs; the blocks' routine performance can also be established; a more accurate determination can be made of the difference in the field indices of open and closed blocks in an assembled electromagnet under trigger fields; and a topographic study can be made of the magnetic field for total particle extraction from the accelerator.

REFERENCES

1) V.F. Kuzmin, Dissertation, IHEP, Serpukhov, 1966.

2) I.Ya. Korolkov et al., IHEP preprint, SKU 68-18-K, Serpukhov, 1968.

3) Yu.S. Glutchov et al., IHEP preprint, SKU 67-44-K, Serpukhov, 1967.

Table 1

Amount of primary information

Work stage	Amount of information in 3- and 4-decimal figures
1. Study of magnetic performance of accelerator elements	700,000
2. Topographic study of the fringing fields of accelerator elements	100,000
3. Study of the magnetic performance of the elements in the beam transport system (per 1 channel).	15,000-20,000
4. Topographic study of the magnetic field of physical assemblies (per 1 assembly).	100,000

Table 2

Basic performance of the apparatus

Element	Performance
1. Digital voltmeter	Relative accuracy $+1 \times 10^{-3}$ Measurement time - 150 μsec
2. Digital microsecond meter - frequency meter	Discreteness 0.1 μsec
3. Current regulator	Relative instability $+1 \times 10^{-4}$
4. Multichannel time detector (timer)	Discreteness in each channel 1 μsec
5. Operational amplifier	Effective drift voltage 10 μV, linearity 2×10^{-4}

Figure captions

Fig 1 Block diagram of the automatic electronic measuring apparatus

1 - Permalloy detectors
2 - Nuclear resonance detectors
3 - Electronic resonance detectors
4 - Kholla detectors
5 - Ferrite generating detectors
6 - Induction coils
7 - Current regulator
8a - To the detector
8b - To the detectors
9 - Digital microsecond frequency meter
10 - Integrator
11 - Transformer
12 - Matrices
13 - Memory registers
14 - Commutator
15 - Computer
16 - Punch
17 - Programmer

Fig. 2 General view of the measurement apparatus

Fig. 3 Stand diagram

1 - Generator
2 - Field detectors
3 - Indicator
4 - Pack
5 - Control, geodesic signal
6 - Coordinate mechanism
7 - Electronic apparatus
8 - Punch
9 - Measured pack
10 - Reference pack
11 - Control pack
12 - Control block
13 - Calibrated block
14 - t in sec

Fig. 4 Distribution of packs according to the size of the corresponding performance deviation

Fig. 5 Schematic diagram of the measuring apparatus for the topographic study of the magnetic field in the blocks

1 - Integrator
2 - Digital voltmeter
3 - Computer
4 - Register
5 - Recording
6 - Comparator
7 - Timer
8 - Punch
9 - Reproducer
10 - Tape

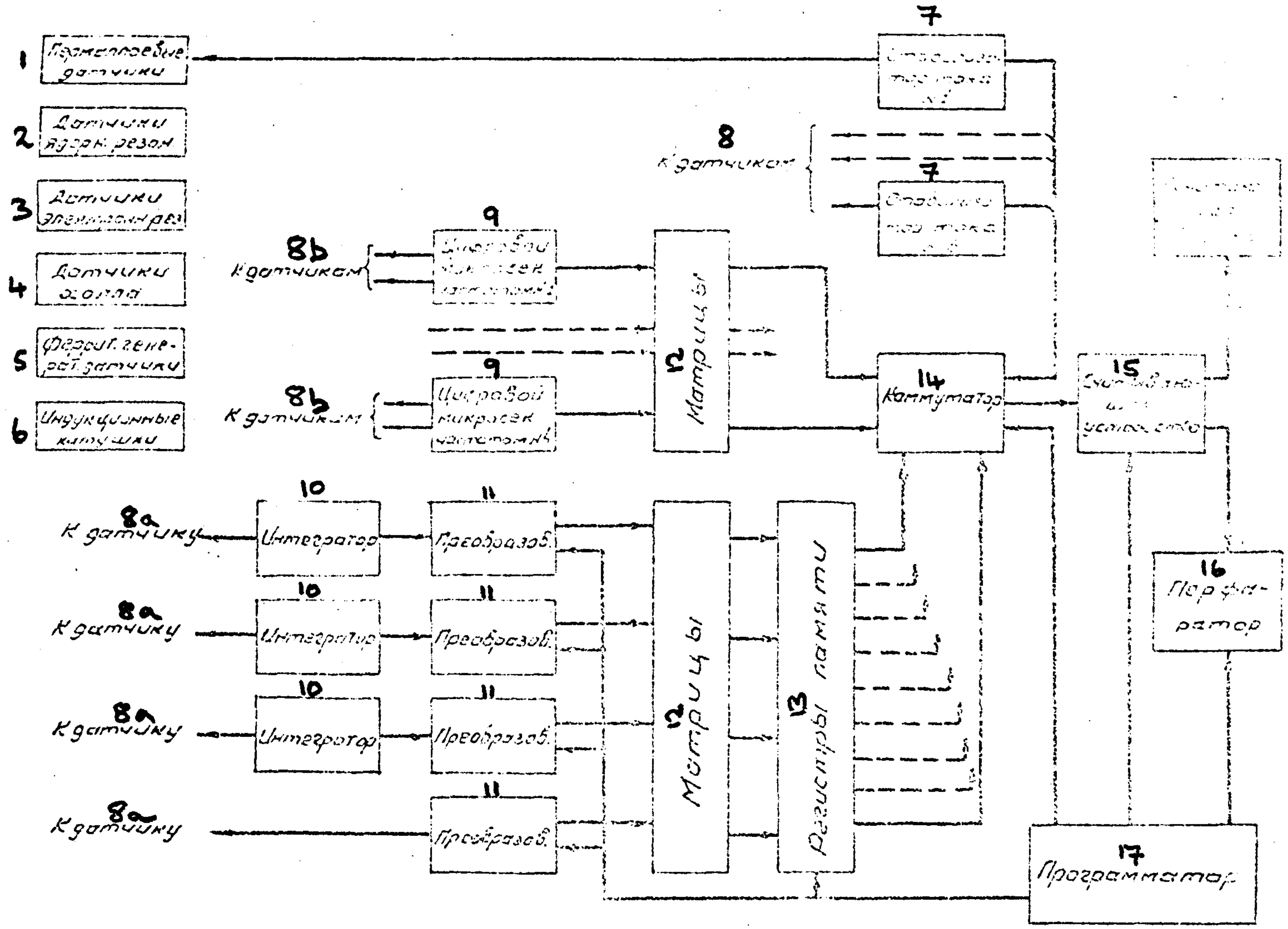

Рис.I. Блок-схема комплекса автоматической электронной измерительной аппаратуры

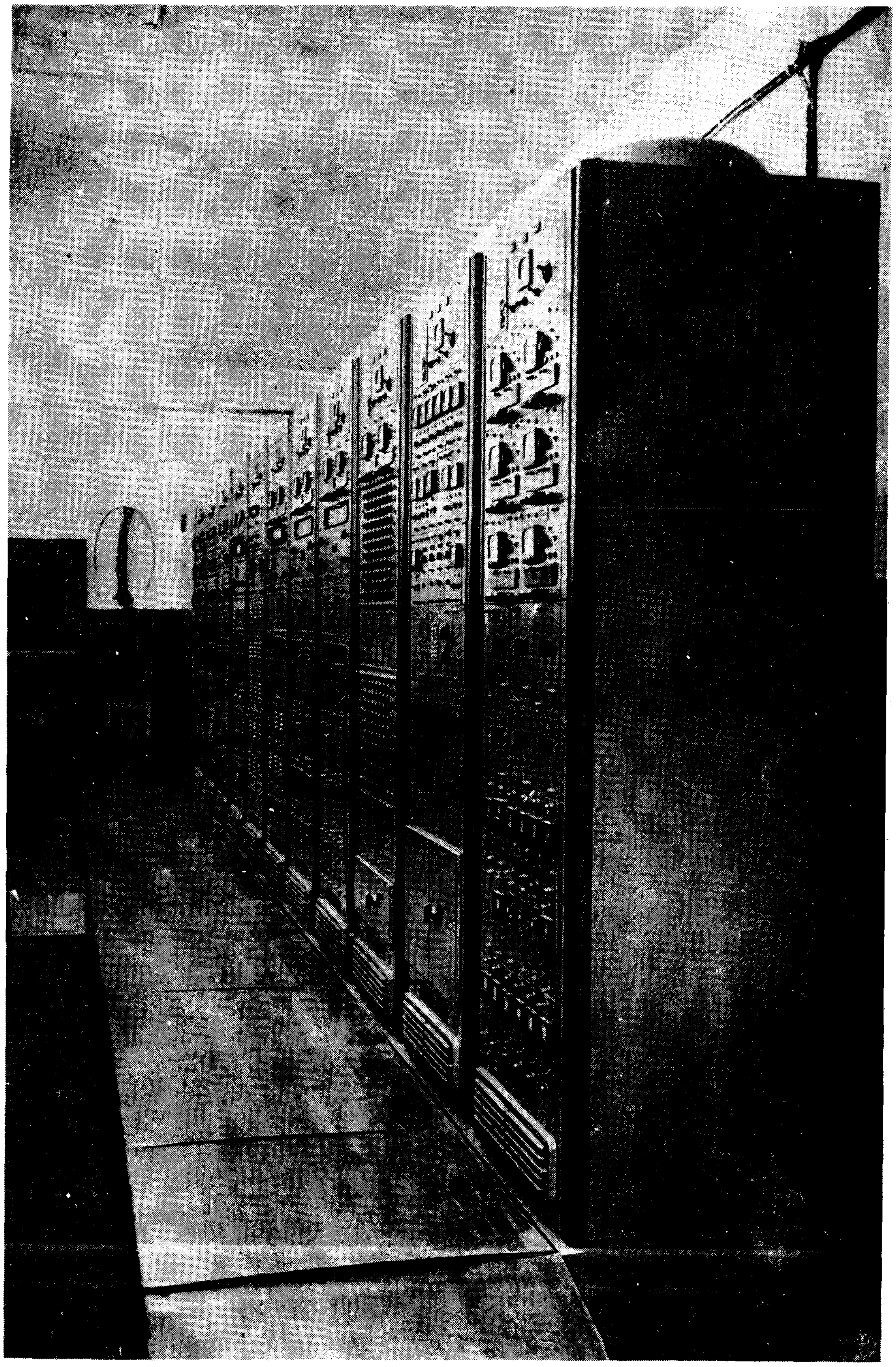

Рис.2. Общий вид аппаратуры измерительного комплекса

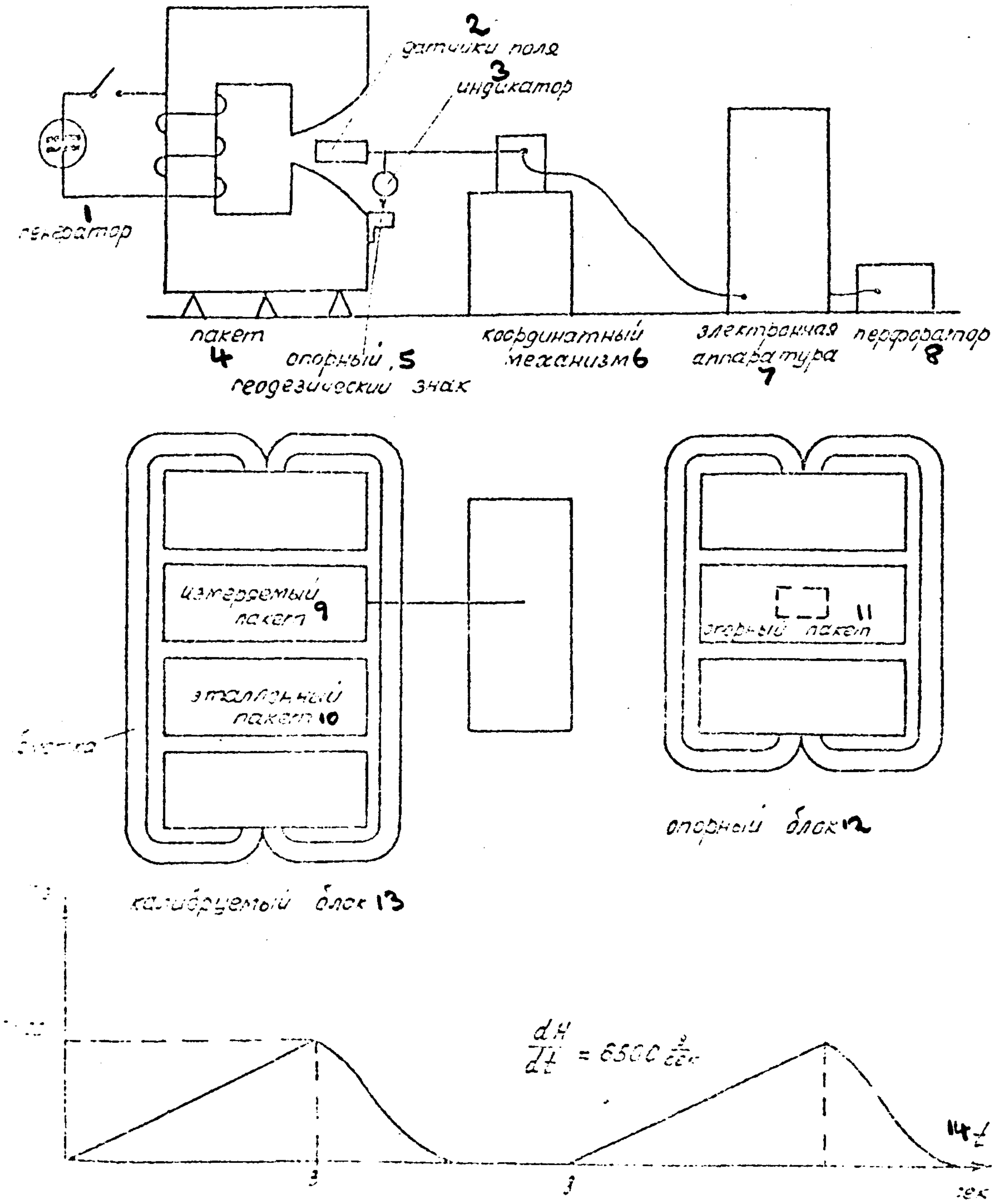

Рис.3. Схема стенда

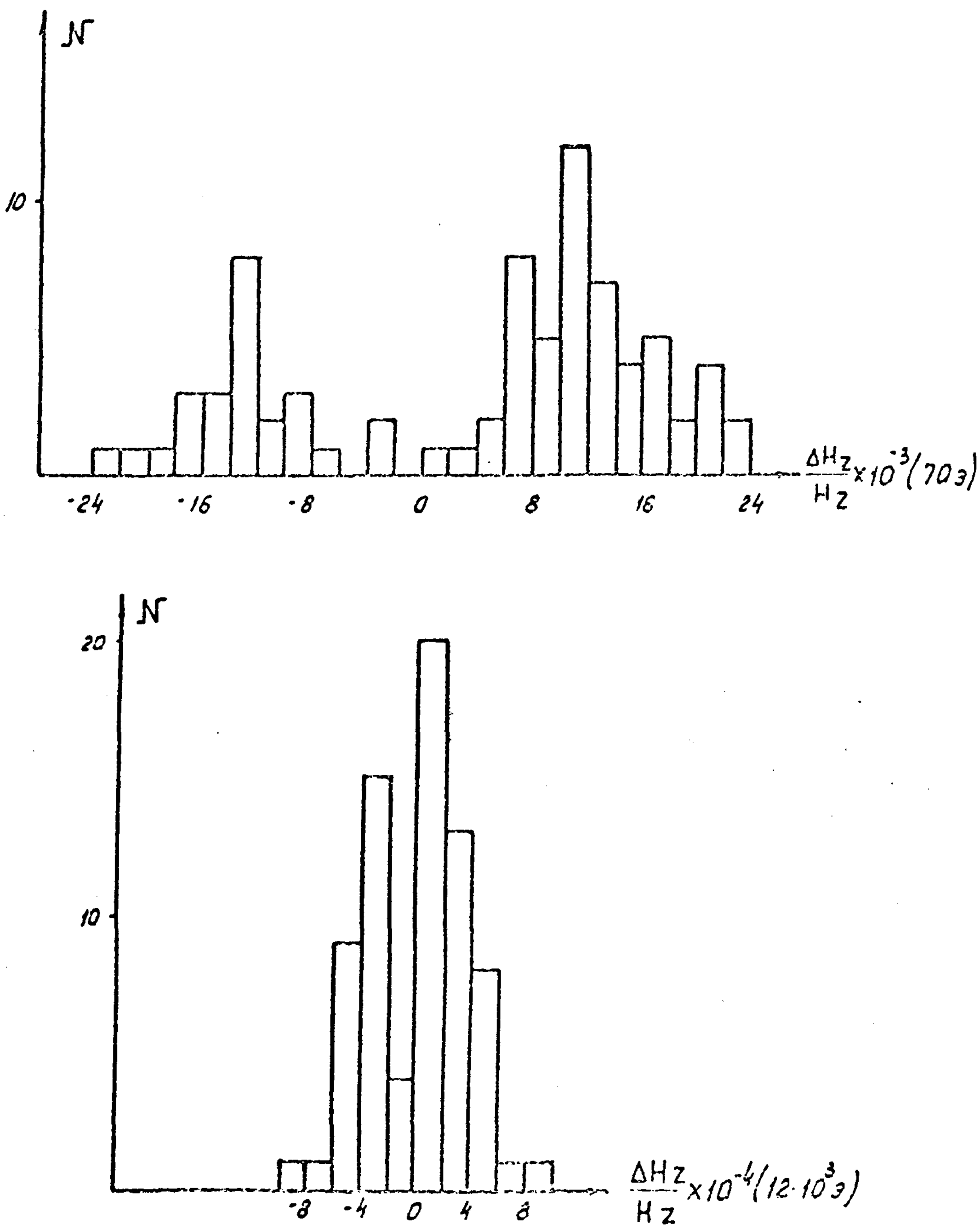

Рис.4. Распределение пакетов в зависимости от величины относительного отклонения характеристик

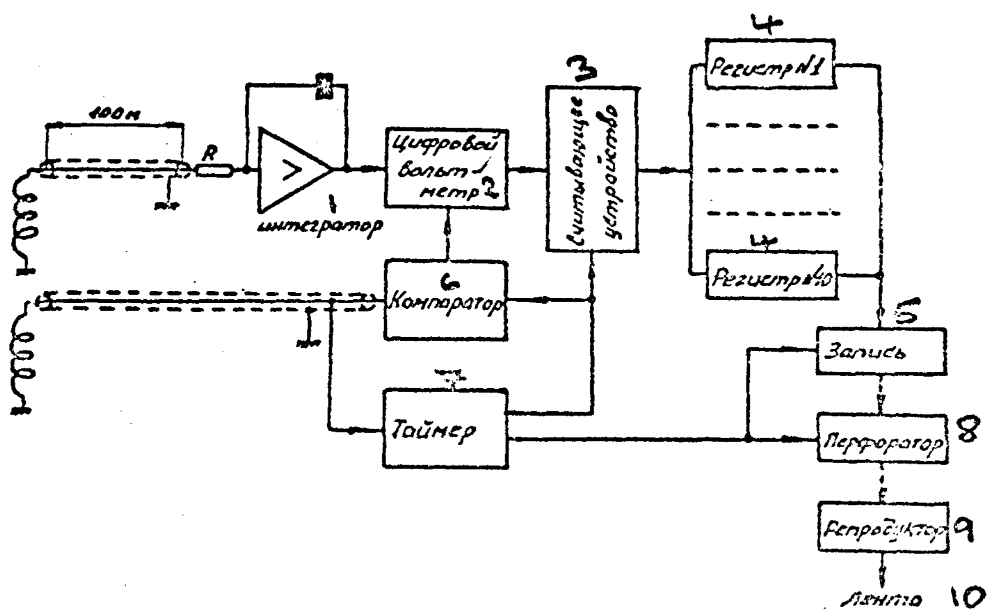

Рис.5. Блок-схема измерительной аппаратуры для изучения топографии магнитного поля в блоках