METROLOGICAL EQUIPMENT FOR CHECKING MEANS OF MEASURING MAGNETICIELDS UNDER NORMAL AND CRYOGENIC CONDITIONS

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The U746 apparatus reproduces steady-field induction \( B = \pm (0.5\text{-}7.5) \text{T} \) in the range from 4.2 to 300°K; the limit to the permissible basic error is \( \pm 0.5\% \). The apparatus can be used in adjusting, testing, and checking means of measuring constant induction having errors of 1.5% or more and in research on magnetic-measurement sensors. The apparatus consists of the following major units: cryostat, inductive magnetic-induction measure, power source for this, field regulator, temperature regulator with power amplifier, coordinate device, current source for magnetic-measurement sensors, analog-digital teslameter, display devices, power supplies, and series resistor in the measure.

The measure is a superconducting solenoid made of NT-50 niobium-titanium wire placed in a KG-150M helium cryostat. To fill the cryostat containing the measure requires 40 liters of liquid helium. The critical induction is 7.51 T. The outside diameter is 143 mm, height 250 mm. The diameter of the useful cold volume is 40 mm. The induction inhomogeneity along the lengthwise axis is not more than 0.1% over \( \pm 5 \text{ mm} \). The instability with current source is \( 10^{-4} \text{ h}^{-1} \), and with frozen field \( 10^{-6} \text{ h}^{-1} \). The current supply can handle a measure of inductance up to 20 H. Current yield from 5 to 300 A. The induction can be produced at various rates, but not more than 0.2 T/min up to \( B = 6 \text{ T} \); 0.15 T/min up to \( B = 6.5 \text{ T} \); or 0.1 T/min up to 7.5 T. The increment in \( I \) in any given range is provided with an error of not more than \( 10^{-4} \text{ I}_{\text{max}} \), while \( I \) is determined from the potential difference across the series resistor by means of a data-display device, which includes digital and pen-recording instruments. The current source is supplied from a three-phase power unit, whose rectifiers are cooled with water at a flow rate of not more than 2 liter/min.

The field regulator provides programmed induction adjustment (current \( I \)); the regulator forms a closed-loop system governing \( I \) with the current source. The field regulator provides the following: current steps of 0.1 A up to 300 A, error 0.05%, linear sweep with halt when the control parameter equals a set value, setting the control parameter equal to the sum of a discrete value and the linear sweep value, and manual control.

The controlled-temperature chamber is a sealed copper heat-exchanger mounted within the working volume and flushed on the outside by helium gas. The evaporating helium is vented through a valve providing an excess pressure in the cavity of 20-30 kPa (0.2-0.3 atm). The helium passes through a thermal decoupling coil to the heater and acquires a temperature set by the regulator and flushes the chamber. The temperature at the center of the measure can be set as 4.2°K or in the range from 6 to 300°K. The temperature nonuniformity in the working volume is not more than 1.5°K.

The temperature regulator sets the control law; it operates with the power amplifier in a closed-loop control system. The temperature setting step is 0.1°K. The time required to reach limiting temperatures of 6-300°K is not more than 1 h. The temperature instability in the chamber is not more than 0.5°K/h. The temperature is recorded by means of a display device, which contains a pen recorder.

The coordinate device sets sensors at the center with an error of not more than 0.1 mm; six sensors can be accommodated. The cavity containing them is sealed from the cavity containing helium.

The current source for the sensors provides a stabilized voltage. Current range from \( 10^{-6} \) to \( 10^{-1} \), load voltage 10 V. Current drift in the range from \( 10^{-6} \) to \( 10^{-5} \) A not more than 0.1 h\(^{-1} \), and in the range from \( 10^{-5} \) to \( 10^{-1} \) A, not more than \( 10^{-3} \text{ h}^{-1} \). Voltages, 1, 2, and 5 V at load current 100 mA. Voltage drift not more than \( 10^{-3} \text{ h}^{-1} \).

The analog-digital teslameter measures the steady induction by means of NMR at 4.2\textdegree K in $^{27}\text{Al}$; it measures the constant for the measure in the range from 0.5 to 10 T with an error of not more than 0.05\% for a field inhomogeneity not more than 0.1\%/cm.

The power supply provides all the units with stabilized voltages, apart from the measure current source. Total power drawn not more than 3.5 kVA.

The U747 apparatus reproduces alternating magnetic induction in the frequency range from 10 to 1000 Hz at 4.2 and 77\textdegree K and in the range from 283 to 373\textdegree K. The limits to induction-amplitude reproduction are 0.01, 0.0316, 0.1, 0.316, 1, and 2 T. The limit to the basic referred error of measurement in the range from 10 to 1000 Hz is ±1.5\%. The apparatus can be used in adjusting, testing, and checking means of induction measurement having errors of 5\% or more and in testing magnetic-measurement sensors. The main units are as follows: cryostat, thermostat, two inductive induction measures, current source, teslameter, data display, field stabilizer, coordinate devices, and power supply.

The IMMII and IMMI2 inductive measures are toroidal coils containing 49KZFA strip Supermendur cores, gap width 2 ± 0.1 mm, containing the sensors. IMMII in the thermostat is used to reproduce induction between 283 and 373\textdegree K. The IMMII winding is made of flat copper strip having a total cooling area of 104 cm$^2$, which means that the winding temperature rises by not more than 3-4\textdegree K at 20 A. Outside diameter of the IMMII 215 mm, inside diameter 140 mm. The IMMI2 is located in the KG15/150-1 cryostat for reproducing induction at 4.2 and 77\textdegree K. The winding is hyperconducting ultrapure A999 aluminum wire, which greatly reduces the heating and coolant evaporation. The eddy-current loss in the Supermendur is also small and minimizes coolant consumption. These inductive measures reproduce the maximal induction $B_{\text{max}}$ and the RMS induction $B_{\text{rms}}$ for sinusoidal fields from $10^{-3}$ T up to the induction given by $\Pi = \frac{B_{\text{max}} f}{P}$, where $f$ is the fundamental. At $10 \leq f_1 \leq 20$ Hz, $\Pi_1 = T \cdot \text{Hz}$, $P_1 = 4 T \cdot \text{Hz}$, At $20 \leq f_2 \leq 50$ Hz, $\Pi_2 = 7 T \cdot \text{Hz}$, $P_2 = 5 T \cdot \text{Hz}$. For $50$ Hz $\leq f_3 \leq 1000$ Hz, $\Pi_3 = 90 T \cdot \text{Hz}$, $P_3 = 64 T \cdot \text{Hz}$.

The induction inhomogeneity in the working volume 16 × 4 × 2 mm is not more than 2\%/cm; the drift rate is 35 · 10$^{-4}$ h$^{-1}$. The current source consists of G3-112 and G3-109 low-frequency oscillators, a UPV-15-1 wired broadcasting amplifier, and Ch3-54 frequency meter. The G3-112 is used to produce the induction in the range from 10 to 20 Hz, while the G3-109 is used from 20 to 50 Hz, and in conjunction with the UPV-15-1 from 50 to 1000 Hz.

The teslameter employs an induction sensor. Direct conversion is applied with input integration. The teslameter acts as induction meter for the measure in checking means of measurement and at the same time serves as alternating-voltage source in the field stabilizer. The sensors are placed fixed in the gaps in the IMMII and IMMI2, which also contains the sensor for the means of measurement under test. The data display includes various instruments: F563 and V4-13 voltmeters, SI-90 oscilloscope, and S6-9 nonlinearity meter, which together provide data on $B_{\text{max}}$ and $B_{\text{rms}}$ as well as monitoring the induction curve. Another display device enables one to determine the root-mean-square value of $B$ from a pointed instrument, the input being from an RMS detector forming part of the field stabilizer, which provides direct current. The induction stability is improved when the measure is supplied from the UPV-15-1 amplifier.

The coordinate device sets the sensors in the gap with an error of not more than 1 mm. It can accommodate two sensors together. The power drawn by the supply units from the three-phase line (380 V, 50 Hz) is not more than 34.5 kVA and from the single-phase 220-V, 50-Hz line not more than 960 VA.

The U738M apparatus reproduces steady inductions of ±(0.1-10,000) \mu T on three mutually perpendicular axes. The ranges are 1, 10, 100, 1000, and 10,000 \mu T. The limit to the basic reduced error is ±0.3\%. The apparatus is intended for adjusting, testing, and checking means of measuring steady induction having an error of 1\% or more. The main units are the E787 and E788 inductive induction measures, current source for them with field regulator, and display devices.

The E788 three-component measure consists of three mutually perpendicular Helmholtz coils and is intended for providing three mutually perpendicular magnetic axes for testing in turn with fields from 0.1 to 1000 \mu T. The deviation from orthogonality between the axes is not more than 30\'. A rotating device enables one to turn the Helmholtz coils around the vertical axis through ±10° to bring the magnetic axes for the horizontal components into coincidence with those of the instrument within 5\'. The single-component E787 is a solenoid and reproduces inductions between 1000 and 10,000 \mu T along its axis. The working volume in the E788