INSTRUCTION MANUAL

FOR

MAGNETIC SUSCEPTIBILITY BRIDGE

KAPPABRIDGE

KLY - 2

Geofyzika n. p. Brno
Czechoslovakia

CONTENTS

1. GENERAL INFORMATION

1.1 BASIC FEATURES

The **Kappabridge KLY-2** is designed for measuring the magnetic susceptibility of rocks and its anisotropy. Its operation is based on measurements of inductivity changes in a coil due to a rock specimen.

In principle the instrument represents a precision semi-automatic autobalance inductivity bridge. It is equipped with automatic zeroing and automatic compensation of the thermal drift of the bridge unbalance. The data measured is shown in the digital display and besides it is put out on the connector in the parallel BCD code.

The standard pick-up unit is designed for measuring regularly shaped rock specimens of a volume of 10 cm^3 or of fragments in a measuring vessel of a volume of 40 cm^3. As an option, a pick-up unit for measuring regularly shaped rock specimens of a volume of 65 cm^3 or of fragments in a measuring vessel of a volume of 240 cm^3 can be delivered. The measuring coils of both the units are designed as 6th-order compensated solenoids, with a remarkably high field homogeneity.

The KLY-2 bridge has high accuracy, fast measuring rate and an outstanding sensitivity that makes it possible to measure even rocks with very weak magnetic properties. Owing to these features the instrument can be widely utilized in research into the magnetic properties of rocks, as well as for routine measurements in geophysical survey.

The output of the bridge can be connected to a data recording or to a data processing device via an appropriate interface.

The manufacturer can supply the KIM-20 Asynchronous Interface Module for interfacing the KLY-2 to a teletype (full duplex, 20 mA current loop). The teletype prints a listing of the data measured and simultaneously punches the data on a punch tape for further processing.

By means of the KIM-20 Interface Module the KLY-2 can also be connected to a computer or a terminal with an IEC RS 232 C standard input interface.

1.2 SPECIFICATIONS

Kappabridge KLY-2 comprises

measuring unit	KLY-2.0
standard pick-up unit	KLY-2.1
pick-up unit for large specimens (optional)	KLY-2.2

	Pick-up unit	
	KLY-2.1	**KLY-2.2**
Inner diameter of the pick-up coil	43 mm	76 mm
Nominal specimen volume	10 cm^3	65 cm^3
Cubic specimen *)	20 x 20 x 20 mm	38 x 38 x 38 mm
Cylindrical specimen *)	ϕ 25.4 x 22 mm	ϕ 46 x 40 mm
Spherical specimen		ϕ 50 mm
Measuring vessel for fragment specimens	40 cm^3	240 cm^3
Magnetic field intensity (r.m.s. value)	300 A/m	
Field homogenity **)	0,2 %	
Operating frequency	920 Hz	
Measuring ranges	100, 200, 400, 1 000, ... 200 000 x 10^{-6} (SI) 11 ranges	

Digital display	0 - 1 999 units
Output	parallel BCD
Sensitivity for specimen of nominal volume 10 cm^3 ($65 cm^3$)	4×10^{-8}
Accuracy within one range	± 0.1 % ± 1 count
Accuracy of the range divider	± 0.3 %
Accuracy of absolute calibration	± 3 %
Power requirements	220 V ***) 50/60 Hz
Power consumption (with the KIM-20 Interface)	60 VA
Operating conditions	
Ambient temperature	10°C - 35°C
Relative humidity	up to 80 %
Dimensions, weight	
Measuring unit KLY-2.0	554 x 170 x 389 mm 20.5 kg
Standard pick-up unit KLY-2.1	208 x 260 x 223 mm 7.5 kg
Large specimen pick-up unit KLY-2.2	380 x 428 x 374 mm 26.5 kg

Notes:

*) Holders of specimens of slightly different size can be supplied on request.

**) Within the cylindrical space 43 mm in diam. (76 mm) and 41 mm in height (72 mm).

***) Standard instrument. **Kappabridge** adapted for another mains voltage can be supplied on request.

1.3 SAFETY REQUIREMENTS

The metal surface of the instrument, the panel, the handles and the covers are separated by double reinforced insulation from the inner live parts with dangerous voltage. In this way, protection against dangerous touch voltage is ensured in accordance with electrotechnical safety regulations. Therefore, there is no terminal on the instrument for connecting protective earthing.

The zero point of the bridge connected with the chassis of the instrument is earthed through the operational earthing terminal. This operational earthing does not function as a protective earthing and can even be eliminated provided that the function of the bridge does not deteriorate under the given conditions.

The mains voltage is in the power-input part of the instrument up to the main insulating transformer. The voltage in the other parts of the instument is not dangerous.

The floor in the room in which measurements are made must be covered with dry insulating material, e.g., rubber.

When working with the instrument the operator must not touch electric instruments with conductive (metal) surfaces and earthed objects, e.g. water piping, conductive building constructions, etc.

The instrument can be moved or carried only when disconnected from the mains.

The operator must be properly trained for operation with the instrument. He must follow Instruction Manual and observe safety regulations.

The instrument can be operated only if it is in good condition. In case of unexpected malfunction or damage the instrument must immediately be disconnected and must not be operated before it has been repaired.

If the instrument has not been in use for a longer time, it must be cleaned and checked for damage or malfunction with respect to safety. This should also be performed at regular intervals. Damaged or worn parts should be exchanged to prevent malfunction.

A slow fuse (type T, 250 mA for 220 V, 400 mA for 120 V) serves for protection against short-circuit and overload.

Fuses from the manufacturer should be used only. If a fuse with a different characteristic is used, the protection is not effective.

Other devices e.g. a desk-calculator, a computer, a teletype, a voltmeter or an oscilloscope can be connected to the instrument via the appropriate interface, if needed.

The zero point of an additional device which is connected via an appropriate connector with the zero point of the bridge, must either be floating or must have zero potential.

The construction, testing and quality control of the instrument are in accordance with the Czechoslovak State Standard ČSN 356501 - ELECTRONIC MEASURING INSTRUMENTS - Safety Requirements.

2. PRINCIPLE OF OPERATION

2.1 BRIDGE NUCLEUS

The bridge nucleus, i.e. the bridge circuit proper, is illustrated in a simplified form in Fig. 1. The primary of the differential transformer **Tr** is supplied with an **AC** voltage of 920 Hz frequency from the generator **G.**

On the secondary it produces two voltages of the same amplitude and opposite phase.

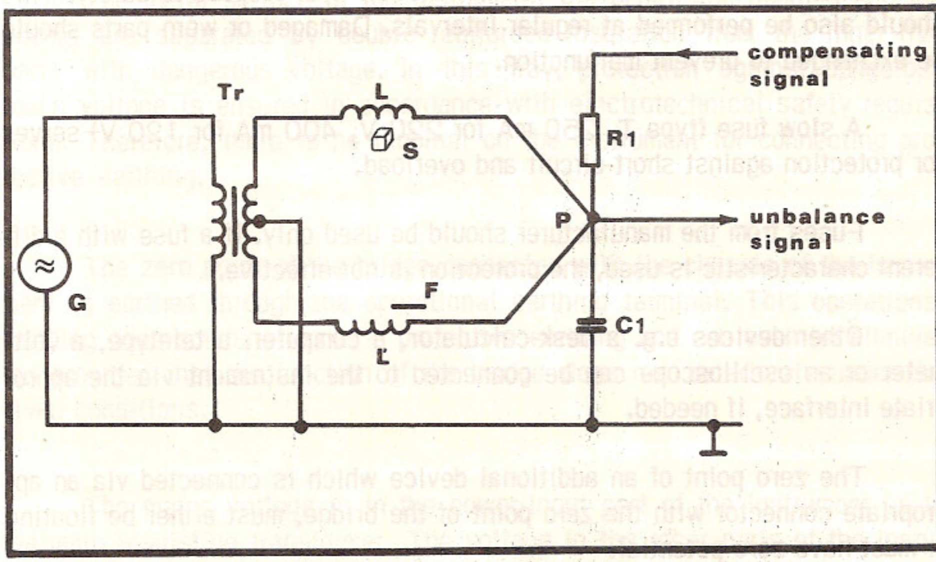

Fig. 1 Simplified circuit diagram of the KLY-2 bridge nucleus

Two measuring coils are connected to the secondary winding of the transformer: the pick-up coil **L** into which the specimen is inserted during the measurement, and identically designed balancing coil **L´** equipped with a small ferrite slug **F** for manual zeroing of the bridge.

The terminals **L, L´** that are not connected to the transformer **Tr** are connected to the bridge network output point **P** from which the signal of unbalance is taken for furher processing. The output of the bridge is tuned by means of the capacitor **C 1** connected between the point **P** and the zero point of the bridge. (The required selectivity and real output impedance of the bridge network are thus obtained).

To the point **P** the compensating signal, maintaining the balance of the bridge circuit during the measurement, is also fed via the resistor **R 1**.

2.2 THE DIRECT AND THE FEEDBACK BRANCHES

The block diagram of the bridge is shown in Fig. 2. The voltage generated by the generator **1** is fed to the bridge nucleus **2.** (We shall assign the zero phase to this voltage). Besides, the generator **1** supplies two rectangular voltages with the phase $+90°$ and $-90°$, and an auxiliary sine-wave voltage with the phase of $90°$ to an oscilloscope.

The unbalance voltage from the bridge nucleus **2** is amplified by the pre-amplifier **3** and passed to the attenuator **4.** It is then fed to the amplifier **5**, the synchronous demodulator **6**, controlled by the rectangular voltage from the generator **1**, and to the integrator with the low-pass filter **7.**

The digital voltmeter **(DVM) 8** operating on the double-slope integration principle is connected to the output of the low-pass filter. A rather long integration time has been chosen (2 s) in order to achieve effective noise suppression.

So far we have been describing the direct branch of the bridge. As the bridge operates on the autobalance principle, it also comprises a feedback branch. The signal from the integrator with the low-pass filter **7** is passed to the input of the demodulator **18**, controlled by the rectangular voltage from the generator **1.** (We have not paid attention to block **19** yet). The signal is then passed to the amplifier **17** and further to the attenuator **16**, and from its output to the bridge nucleus via the amplifier **10**, see Fig. 1.

Both the attenuators **4** and **16** are switched simultaneously in such a way that the attenuation is constant. The switching is accomplished by the range selector **11** that supplies **DC** signals, controlling the attenuators electronically.

The described feedback loop maintains the zero value of the real unbalance component of the bridge nucleus **2**, which is the principle of the autobalance function. The real unbalance component corresponds to the sus-

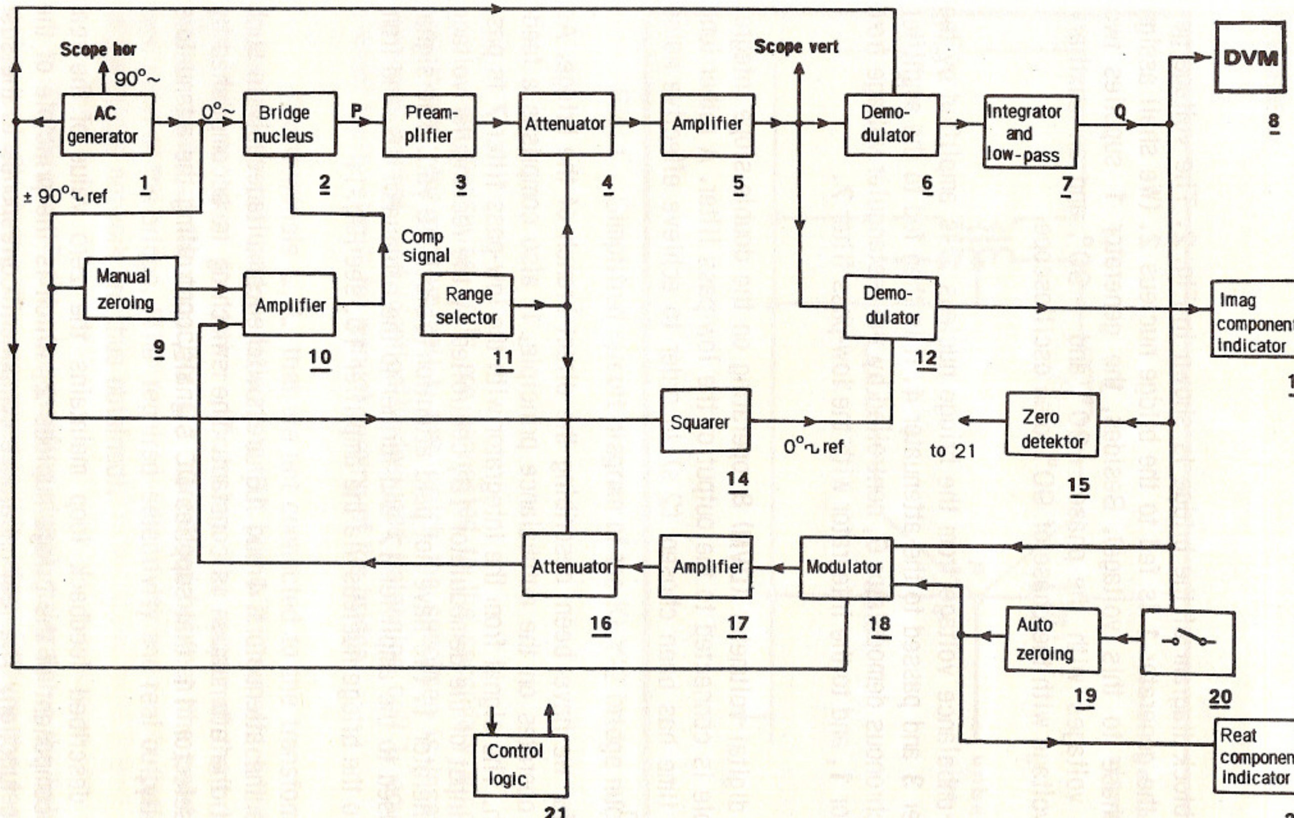

Fig. 2 Schematic block diagram **Kappabridge KLY-2**

ceptibility of the specimen, i.e. to the change of the pick-up coil inductivity.

The principle of measurement is as follows:

Let us assume that the bridge has been zeroed, i.e. there is zero voltage on the input of **DVM 8**, and that the switch **20** is off. (The zeroing will be explained later on). By inserting the specimen into the measuring coil its inductivity will be increased. The induced signal of unbalance will be compensated immediately by the effect of the feedback loop. A voltage proportional to the inductivity change and thus to the susceptibility measured will appear on the input of **DVM 8**.

2.3 ZEROING

To a certain extent the zeroing is automatic and is combined with the automatic compensation of the drift due to changes in the parameters of the measuring coils. By manual zeroing the bridge is brought to the region of automatic zeroing.

The circuit **19** (Fig. 2) for transmission with double integration, i.e. its transfer function F (p) has a double pole at the point p = 0, serves for automatic zeroing and compensation of the drift.

Let us assume that the bridge has roughly been zeroed manually. The switch **20** is off, and let us suppose that also the output of the circuit **19** is disconnected. The voltage on the input of **DVM 8** differs from zero and it changes gradually due to the measuring coils drift. Let us assume that these changes are linear, time-dependent.

Now activate the circuit **19** by connecting its output to the input of the modulator **18** and by turning on the switch **20.** In this way the input voltage of **DVM 8** will be fully zeroed after a certain period.

If we now turn off the switch **20**, neither the immediate value, nor the rate of change of the output voltage of the circuit **19** change because they are stored in its analog memory. Thus the zeroing is preserved for some time.

The assumed disconnection of the output of the circuit **19**, mentioned above, is relevant for the description of its function only. Actually, the output of the circuit **19** is permanently connected to the input of the demodulator **18.**

In the higher ranges, beginning from the 7th, the transfer of the circuit **19** changes so that only one integration is performed. This means that its transfer function has a single pole at the point p = 0. The circuit thus performs the zeroing only and not the drift compensation. In this way steady state is reached sooner.

The automatic zeroing concerns only the real component of unbalance that corresponds to the changes of the inductivity of the pick-up coil. In manual zeroing the switch **20** is always turned on.

The zeroing in the real component is performed by means of a ferrite slug inserted into the balancing coil **L´** by means of a screw (Fif. 1). The screw is set to a position in which the indicator of the real component **22** shows zero.

The indicator **22** is connected to the output of the circuit **19.** This indicator does not indicate the real component of unbalance directly, but the magnitude of voltage that must be supplied by the circuit **19** to achieve balance. However, this is not important for the operator.

The zeroing in the imaginary component is performed by means of a potentiometer in the circuit **9.** From this circuit the necessary zeroing signal is passed via the amplifier **10** into the nucleus of the bridge. The potentiometer is set so that the imaginary component indicator **13** shows zero.

The indicator **13** is connected to the output of the demodulator **12.** The input of the demodulator is connected to the output of the amplifier **5** and is controlled by the reference rectangular voltage generated by the squarer **14** of the voltage of the generator **1.**

The manual zeroing need not be accurate. In the course of measurement it should be repeated only if the deflection of any of the indicators **22, 13** exceeds about 50 % of the scale range to either side.

2.4 CONTROL LOGIC

The measuring process is controlled by the logic **21** gathering information from individual circuits and giving the necessary commands. The logic is operated by the push-button **PB1 START/RESET**, see Fig. 7.

The bridge operates in four statuses. Each of them is indicated by a luminiscence diode:

Status	**Diode**
WAIT	1. red
READY	green
MEASURE	yellow
HALT	2. red

WAIT. The switch **20** is on, the automatic zeroing is on. The signal VTS for the voltmeter start (see the connectors on the rear panel of the measuring unit, Fig. 8) is at the logic level 1. **DVM** measures the residual unbalance repeatedly. The push-button **PB1** is disabled. When the zeroing has been completed, the signal transmitted by the zero detector **15** to the control logic changes from the level 0 to the level 1, after approx. 2 s the bridge enters the status READY.

READY. This status does not differ from the previous one substantially. The push-button **PB1** is enabled. When it is pressed, the bridge passes to the status MEASURE. If the balance is disturbed in the status READY, the bridge returns to the status WAIT.

MEASURE. After reaching this status, the switch **20** is turned off and thus the automatic zeroing is eliminated. **DVM** is blocked and internally cleared when the signal VTS (Fig. 8) drops to 0, and a short pulse of the level 1 appears in the signal VLC. Immediately after enterning the status MEASURE the specimen is inserted for measurement.

After approx. 4 s, the voltmeter is started for a single measurement by a pulse of the level 1 in VST. After the integration has been completed (2 s) a pulse of the level 1 in the EOI signal is sent; an accoustic signal is generated in the control logic indicating that the specimen should be pulled out.

Approx. 3 s after the integration has been completed, the circuit converts to the status HALT.

HALT. The automatic zeroing is resumed since the switch **20** is turned on. The reading on the voltmeter does not change as the signal VST remains at the level 0. In this status, the reading can be read off and recorded (also automatically). The push-button **PB1** is enabled. If it is pressed, the bridge enters WAIT or READY according to the zeroing state.

2.5 OSCILLOSCOPE AND EXTERNAL VOLTMETER

An oscilloscope and an external voltmeter may be used to check some of the instrument functions.

For this purpose a special measuring cord is delivered, with a connector on one end and six banana plugs on the other. The connector is plugged into the connector AB on the rear panel of the measuring unit, see Fig. 8. The banana plugs are connected as follows:

Outlet	Colour	Connection
short	green	zero terminal of the scope
short	blue	horizontal input of the scope
short	red	vertical input of the scope
long	green	zero terminal of the voltmeter
long	blue	"low" terminal of the voltmeter
long	red	"high" terminal of the voltmeter

In this way the horizontal and the vertical inputs of the scope are connected to the points marked in Fig. 2; the external voltmeter is connected in parallel to the digital voltmeter of the bridge.

The measurement by the scope is performed in the status WAIT or READY. The basic pattern is a horizontal ellipse. The narrower the ellipse, the better the zeroing of the imaginary component. If the ellipse is inclined, the feedback is not working. This may be due, in particular, to serious detuning in the real component.

On the screen of the scope we can observe noise and disturbing signals that are induced in the measuring coils. In this way we can estimate whether the operation can be performed in the environment given.

The external digital voltmeter can be used for checking the function of the internal voltmeter. A count on the digital display DATA represents approx. 5 mV.

Sometimes it is useful to utilize an external analog voltmeter with zero in the middle of the scale. Noise and spurious signals, in particular the pulse ones, can be observed in the status READY.

3. INSTRUMENT LAYOUT

The instrument consists of two independent units - the pick-up unit KLY-2.1 (or KLY-2.2), and the measuring unit KLY-2.0. A general view of the instrument with the pick-up unit KLY-2.1 is in Fig. 3.

3.1 PICK-UP UNITS KLY-2.1 and KLY-2.2

The pick-up unit comprises the nucleus of the bridge **2** - Fig. 2 (the transformer, the pick-up coil, the balance coil and other passive components), and the pre-amplifier **3** located on the printed-circuit card denoted PAM1 and PAM2 in the pick-up unit KLY-2.1 and KLY-2.2, respectively. The pre-amplifiers differ in the value of one resistor only.

The KLY-2.1 with the cover removed is illustrated in Fig. 4. The design of the KLY-2.2 is almost identical.

A cross-section view of the pick-up unit KLY-2.1 is in Fig. 5 a:

1 - ceramic former
2 - winding
3 - tubular inset
4 - base plate

The tubular inset defines the position of the specimen during the measurement, prevents mechanical contact of the specimen with the coil, and acts as thermal insulation.

Fig. 5 b shows the field homogenity along the axis of the pick-up coil of the unit KLY-2.1.

A cross-section through the KLY-2.2 pick-up coil is illustrated in Fig. 6 a. The individual items are identical with those of the KLY-2.1 pick-

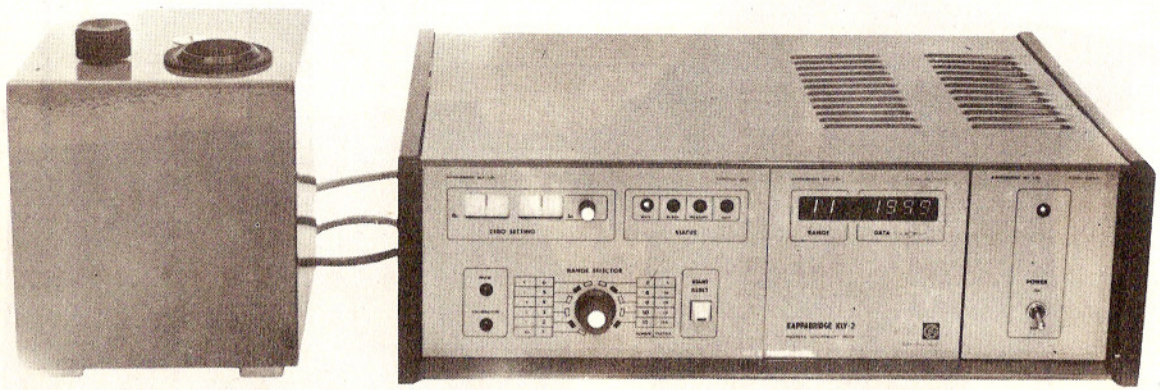

Fig. 3. General view of the **Kappabridge** measuring unit KLY-2.0 with the standard pick-up unit KLY-2.1

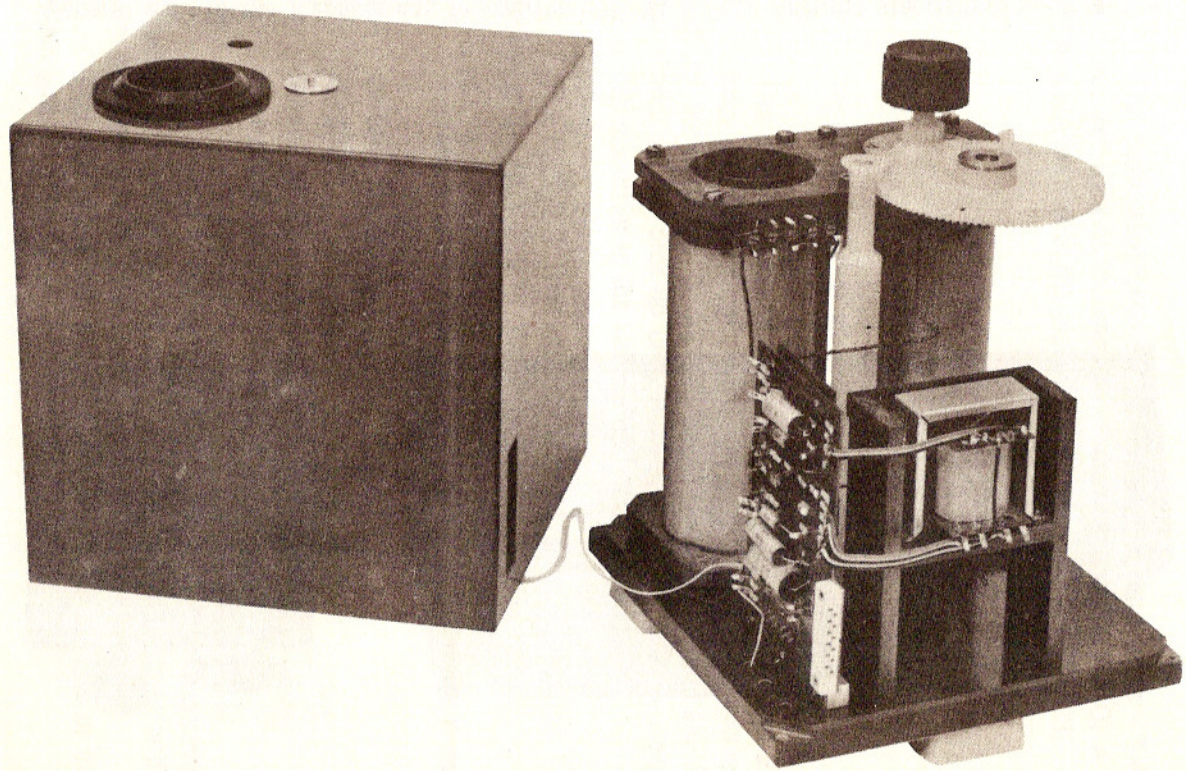

Fig. 4. Standard pick-up unit KLY-2 with cover removed

-up coil. The tubular inset is designed in a rather different way. It is not mounted on the base plate, but suspended from the case of the unit. Thus a deformation of the pick-up system by the weight of the specimen is almost avoided.

Fig. 6 b shows the field homogeneity along the axsis of the pick-up of the unit KLY-2.2.

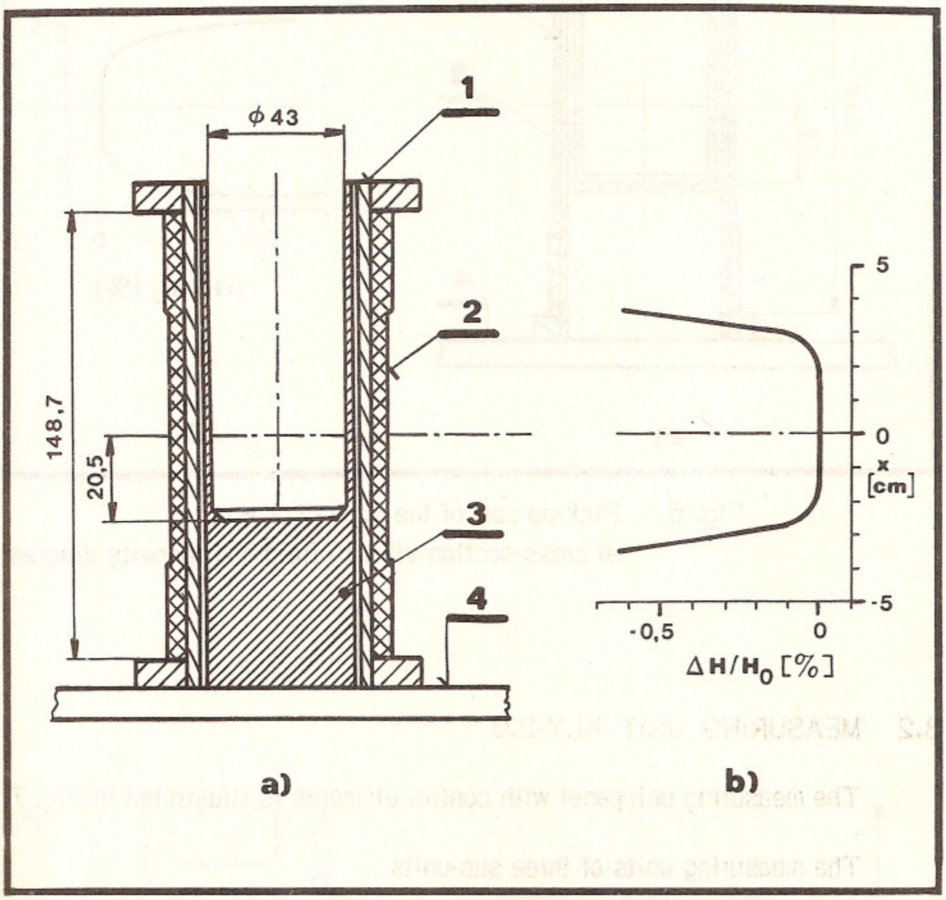

Fig. 5. Pick-up coil of the KLY-2.1 unit
a) cross-section view
b) field homogeneity diagram

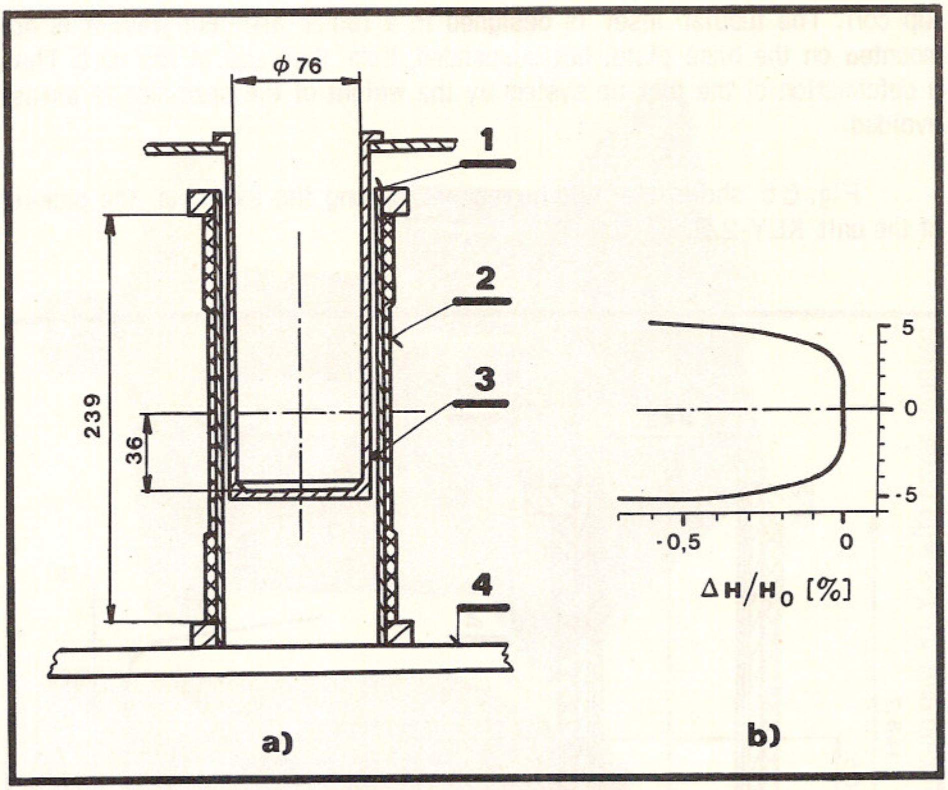

Fig. 6. Pick-up coil of the KLY-2.2 unit
a) cross-section view b) field homogeneity diagram

3.2 MEASURING UNIT KLY-2.0

The measuring unit panel with control elements is illustrated in Fig. 7.

The measuring units of three sub-units:

a) control unit
b) digital voltmeter
c) power supply

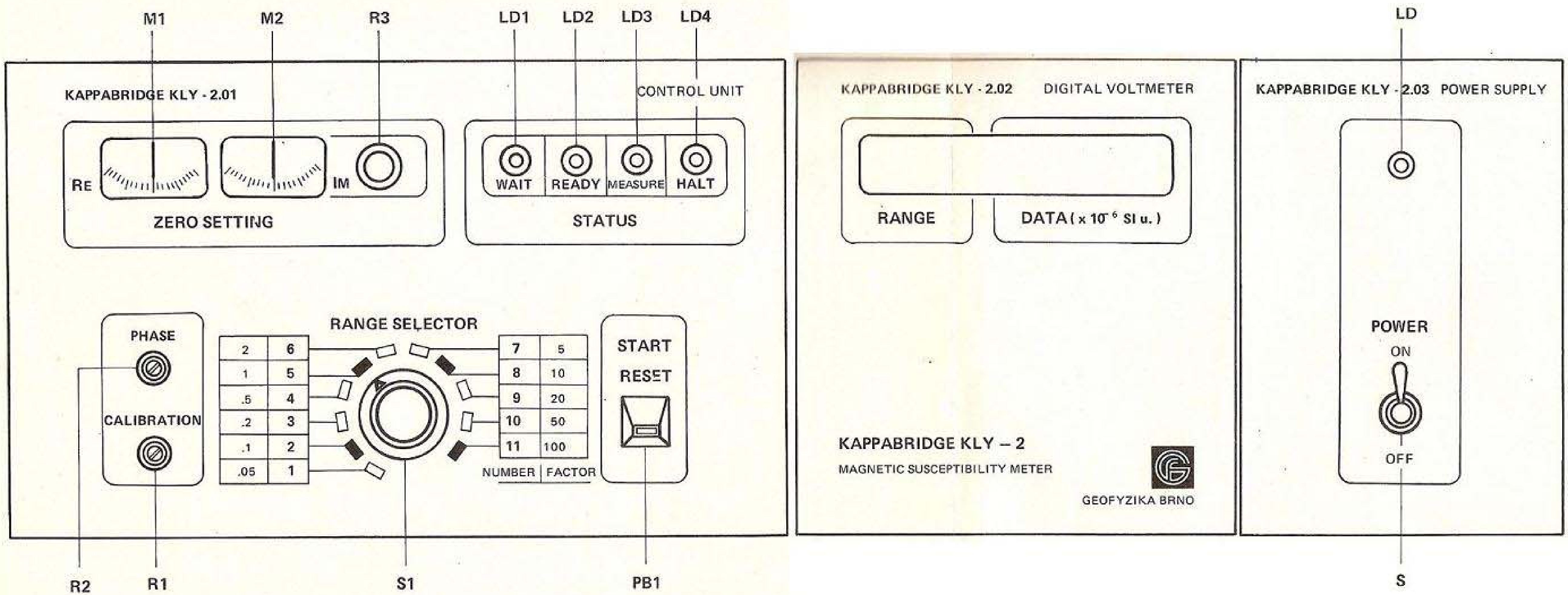

Fig. 7 Front panel of the measuring unit KLY - 2.0

3.2.1 Control unit

The control unit comprises all electronic circuitry of the bridge proper with the exception of the pre-amplifier PAM1 (PAM2), housed in the pick-up unit.

Control elements and indicators:

Designation		Function
M1	R_E	Real component indicator **22***).
M2	I_M	Imaginary component indicator **13**.
LD1 ÷ LD4	WAIT, READY MEASURE, HALT	LED diodes indicating the status of the instrument.
R1	CALIBRATION	Calibration potentiometer linked with modulator **18**.
R2	PHASE	Potentiometer for setting the phase shift of the direct branch. It is linked with the pre-amplifier **5**.
R3	I_M	Potentiometer for manual zeroing in the imaginary component. It is linked with the manual zeroing circuits **9**.
S1	RANGE SELECTOR	Range selector linked with the CCV card, see below.
PB1	START/RESET	Push-button for control of the measuring process.

All these elements are mounted on the ASP sub-panel.

There are 11 cards at 10 planes inside the control unit. Viewed from front they are numbered from left to right.

*) The underlined numbers refer to the respective blocks in Fig. 2.

Position	Designation	Function (contents)
1	**ADB**	Attenuator **4**, amplifier **5**, demodulator **6**, integrator and low-pass filter **7** (part).
2	**AZI**	Aut. zeroing circuit **19** (part), zero detector **15**, squarer **14**, demodulator **12**.
3a (front)	**TZ P64**	Commercial operational amplifier, this belongs to the integrator and low-pass filter **7**.
3b (rear)	**TZ P64**	Commercial operational amplifier within the aut. zeroing circuit **19**.
4	**AFB**	Modulator **18**, amplifier **17**, attenuator **16**, amplifier **10**, manual zeroing circuit **9**.
5	**GNA**	Generator **1** (part).
6	**GNB**	Generator **1** (part).
7	**APS**	Stabilizer 2 x 15 V.
8	**LGA**	Control logic (part).
9	**LGB**	Control logic (part), stabilizer 5 V.
10	**CCV**	Coding matrices processing the signal from the range selector **11**.

The control unit is enclosed with a couple of so-called printed-circuit side-boards interconnecting the grate at the bottom of the sub-unit. The left-hand printed-circuit side-board is designated LSB, the right-hand RSB.

3.2.2 Digital voltmeter

There is a double display on the panel mounted on the sub-panel DVP. The left half of the display des. RANGE shows the sequential number of the measuring range, the right half des. DATA, shows the measured value.On the panel, there are also decoders and other auxiliary circuits of the display.

Inside the sub-unit there are 7 cards at 6 planes, numbered from the left to the right when viewed from the front.

Position	Designation	Function (contents)
1 a (front)	**TZP64**	Commercial operational amplifier. A part of the integrator.
1 b (rear)	**INTB**	Integrator capacitor, integrating relay, 2 discharging relays, zeroing relay.
2	**CMPB**	Comparator, logic circuits controlling the switching of the respective discharging relay.
3	**LPSB**	Two 5 V stabilizers - one for supplying the voltmeter; the output of the second one is fed to the connector **VC** for supplying the interface.
4	**MST**	Master circuit controlling the individual working statuses of the voltmeter.
5	**OSCB**	Crystal-controlled 100 kHz oscillator, frequency dividers, multivibrator for display blinking.
6	**CNTB**	Counter and buffer memory.

Similarly to the control unit, the sub-unit of the digital voltmeter is enclosed with a couple of printed-circuit side-boards. The left-hand one is designated VSSB, the right-hand VLSB. Besides there is an auxiliary inset printed-circuit board VLIB with a connector on the rear side.