RADIOMETER

Impedance Bridge

type GB6

Electrical

measuring instruments for
industrial and scientific work

RADIOMETER . 72 EMDRUPVEJ . COPENHAGEN NV . DENMARK

790 D

Impedance Bridge

Type GB6

Introduction:

The Impedance Bridge measures impedance in terms of magnitude and phase angle. The range is 1 ohm to 1.1 megohms and —90° to +90°. The instrument is self-contained for measurements at 50, 800 and 10000 cycles and can be used from 20 to 20000 cycles with an external oscillator. Measurements at higher frequencies can be made with reduced accuracy.

The bridge is a convenient instrument for measuring the impedance of filter-networks, loudspeakers, a-f coils, transformers, etc. It is a particular advantage that the built-in meter directly indicates the test voltage, when measuring on iron-cored coils.

Description:

The type GB6 Impedance Bridge operates on a principle laid down by Grützmacher. It provides for the measurement of any impedance by comparison with resistance standards alone without the use of reactance standards. The operating principle is shown in Fig. 1. The four bridge arms are made up by two fixed resistors, A and B, each of 500 ohms, the unknown impedance Z, and the resistor R, which consists of a continuously variable calibrated resistor of 0 to 10 ohms and 5 resistance decades: 10×10, 10×100, 10×1000, $10\times10{,}000$, and $10\times100{,}000$ ohms. The fixed bridge arm A is a potentiometer which is provided with a calibrated

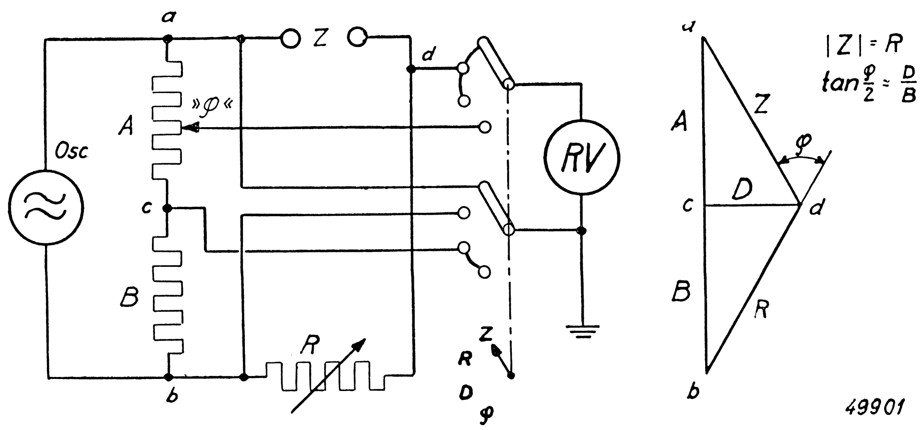

Fig 1. Functional schematic diagram of type GB6 Impedance Bridge

metal dial on which the phase angle φ of the unknown impedance can be read when the bridge has been adjusted. This is done with the aid of a built-in vacuum-tube voltmeter RV which is provided with a switch which has the positions Z-R-D-φ. By means of this switch the vacuum-tube voltmeter can be connected across the unknown impedance, the decade resistor, the bridge diagonal, and the phase potentiometer, respectively. During the adjustment the decade resistor is varied until equal deflections of the vacuum-tube voltmeter are obtained for positions Z and R. Then the magnitude of Z will be equal to the resistance R (which can be read directly from the decades) because the same current flows through Z and R. Next the diagonal voltage is measured (switch position D), and the phase dial is so set that the same voltage is measured with the switch in position φ. The phase angle is then read directly on the dial. The potential diagram fig. 1 right shows how φ is determined. If there is any doubt as to the sign of the phase angle, it can be determined by means of a special device which is not shown in the functional schematic diagram.
The vacuum-tube voltmeter consists of a 2-stage amplifier with a rectifier meter in the output circuit. The sensitivity of the vacuum-tube voltmeter can be set to one of the following input voltages for full scale deflection: 0.1–0.25–0.5–1–2.5–5–10 and 25 volts. The accuracy of the vacuum-tube voltmeter is 2% of full scale in the frequency range 20 to 20,000 cycles. It should be noted, however, that the accuracy of the vacuum-tube voltmeter does not directly influence the accuracy of the measurement, inasmuch as only equal deflections are required during measurement.
The decade resistors are made from non-inductive wire-wound resistors, except the 10 × 100,000 ohm decade which is made from carbon resistors. The accuracy is 0.2% or 0.1 ohm up to 100,000 ohms. Beyond that it is 1%. Equal deflections on the vacuum-tube voltmeter can be read with an accuracy of 0.2 to 0.3%. The final accuracy of the determination of the magnitude of Z is thus better than 0.5% or 0.1 ohm up to 100,000, and above that it is approximately 1%. The calibrating accuracy of the phase angle dial is 0.2°. However, if the measurement of the phase angle is to be accurate, it is imperative that Z be low in proportion to the input impedance of the vacuum-tube voltmeter (5 megohms shunted by 30 pF.)
Attention is drawn to the fact that the voltmeter impedance does not affect the determination of the magnitude.
The bridge can be fed from an external oscillator or from a built-in R-C oscillator with the frequencies 50, 800, and 10,000 cycles. The latter can be coupled either to the bridge or to a pair of output terminals from which the power can be taken for other purposes. The matching impedance can be set to either 500 ohms or 125 ohms. The instruction booklet incorporates a chart showing the maximum undistorted test voltage as a function of Z.

SPECIFICATIONS:

Measuring range:
magnitude: 1 ohm to 1.1 megohm. Phase angle: 0 to ±90°.

Frequency range:
20 to 20,000 cycles, built-in frequencies 50, 800, and 10,000 cycles.

Accuracy of magnitude:
up to 100,000 ohms, better than 0.5% or 0.1 ohm. Over 100,000 ohms, about 1%.

Accuracy of phase angle:
Calibration accuracy of phase dial 0.3°. Measuring accuracy dependent on the magnitude of the impedance. See description.

Vacuum-tube voltmeter:
0.1–0.25–0.5–1–2.5–10–25 volts full-scale deflection. Accuracy: 2% of full-scale deflection

Decade resistors:
0–10, 10 × 10, 10 × 100, 10 × 1000, 10 × 10,000 ohms and 10 × 0.1 megohm. Accuracy: 0.2% or 0.1 ohm up to 100,000 ohms. Over 100,000 ohms, 1%.

Built-in oscillator:
Frequencies: 50, 800, and 10,000 cycles ±1%. Maximum output at 2% distortion 50 and 800 cycles: 1.7 watts, 10,000 cycles: 1 watt.

Power supply:
110, 127, 150, 200, 220, 240 volts, 50–60 cycles. Consumption: 55 watts.

Mounting:
Metal cabinet finished in grey enamel.

Over-all dimensions:
Height: 445 mm.
Width : 405 mm.
Depth : 200 mm.

Net weight:
20 kilos.

Data subject to change without notice.

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IMPEDANCE METER
TYPE GB6

The Impedance Meter can be used for measuring impedances in the frequency range 20 to 20,000 cycles. After the adjustment of a built-in resistor, the numerical value of the impedance can be read on the decades of the resistor. Then a potentiometer is adjusted, and the phase angle is read directly in degrees on its scale. If only the numerical value is of interest, it is important that it can be determined without adjustment for phase angle.

The test voltage can be read on the built-in voltmeter. This is most convenient when testing transformers and coils with iron core whose self-inductance, as is known, depends on the voltage. The Impedance Meter is suitable for determining the constants of A-F transformers, such as self-inductance and leakage inductance, because the built-in generator can operate on 50, 800, or 10,000 cycles. The instrument can also be used as a generator on the above-named three frequencies.

The Impedance Meter consists of the Grützmacher bridge proper, the vacuum-tube voltmeter, the generator, and the eliminator.

THE GRÜTZMACHER BRIDGE

Figs. 1-6 of sheet No. 293-A4 appended to the instructions show the principle of complex measurement of an unknown impedance Z. R is a variable, calibrated, ohmic resistor. r_1 is a potentiometer and r_2 is of exactly the same value as r_1.

Measuring Z (figs. 1 and 2)

By means of a switch the vacuum-tube voltmeter is connected to Z and R alternately, while R is varied until the two voltages are of equal magnitude. In that case $|Z| = R$.

Measuring φ (figs. 3 and 4)

Without changing R measure the voltages e_D and e_φ in turn at the same time rotating the potentiometer until the said voltages are of equal magnitude. The potentials of the 5 points of the bridge will then be situated as shown in fig. 7. It will be seen that the phase angle φ of the impedance is determined by

$$tg\frac{\varphi}{2} = \frac{e_D}{e_r} = \frac{e_\varphi}{e_r} = \text{the potentiometer ratio}$$

The potentiometer dial is so divided that the angle φ is read directly in degrees.

Determining the sign of φ (figs. 5 and 6)
If there is any doubt whether the unknown impedance is inductive ($\varphi > 0$) or capacitive ($\varphi < 0$), this question can be settled in the following way:

Use the same switch as that for measuring $|Z|$ and $|\varphi|$ and set it to positions Z+C and R+C alternately. The sign is then determined as follows:

If the voltage is highest across Z+C, Z is capacitive. If it is lowest across Z+C, Z is inductive.

The built-in resistor consists of 5 decades: 10x0.1 megohm, 10x10,000 ohms, 10x1000 ohms, 10x100 ohms, and 10x10ohms and a variable resistor of 0-10 ohms having a scale divided in halves of ohms. The accuracy of the variable resistor is about 0.1 ohm (inclusive of inaccuracy of setting). The decade of 10x0.1 megohm is made from carbon resistors having an accuracy of 1%, while the other decades are constructed of wirewound resistors with low inductance and an accuracy of 0.2%. The resistors r_1 and r_2 are of equal value (about 500 ohms).

The dial of the phase angle potentiometer is calibrated with an accuracy of 0.3°.

THE VACUUM-TUBE VOLTMETER

The vacuum-tube voltmeter consists of a 2-stage amplifier with a copper-oxide rectifier meter in the output circuit. By means of the switch VOLTS the sensitivity of the vacuum-tube voltmeter can be set to one of the following input voltages for full scale: 0.1 - 0.25 - 0.5 - 1 - 2.5 - 5 - 10 and 25 volts. The accuracy of the vacuum-tube voltmeter is 2% of full scale in the frequency range 20 to 20,000 cycles, but it has no direct effect on the accuracy of the measurement, because only equal deflections are required during measurement. However, the test voltage will be of importance when measuring coils with iron core, as the self-inductance of such coils depends on the voltage across them.

The dynamic input capacity of the vacuum-tube voltmeter is about 30 pF (inclusive of switch and leads). The input resistance is 5 megohms.

By means of the switch "Z-R-D-φ-Z+C-R+C" the vacuum-tube voltmeter can be connected to the bridge in the following 6 ways (as shown in sheet No. 293-A4 appended to the instructions):

fig.	posi-tion	measuring across
1	Z	an unknown impedance
2	R	a basic resistor
3	D	the diagonal of the bridge
4	φ	the phase angle potentiometer
5	Z+C	an unknown impedance in series with a capacity
6	R+C	a basic resistor in series with a capacity

To the left of the above-mentioned switch is mounted a switch for selecting the following values of C when determining the sign:

300	pF
1, 000	"
3, 000	"
10, 000	"
30, 000	"
0, 1	μF
0, 25	"
1	"
4	"

THE GENERATOR

The built-in RC generator can operate on 50, 800 or 10, 000 cycles, and its output voltage can be varied continuously by means of the two knobs OUTPUT. The output transformer of the generator is provided with 2 windings which by means of the switch EXT. GEN. - Z<150Ω - Z>150Ω can be connected in parallel (position "Z< 150Ω") or in series (position "Z>150Ω"). By this means it is always possible to obtain a fairly good impedance match between generator and bridge. Fig. 9 illustrates the highest test voltage obtainable with a sufficiently low distortion. If the switch is set at position EXT. GEN., an external generator can be connected to the bridge at the terminals GEN. MAX. 50V. The built-in generator will then be disconnected. In the position GEN. the built-in generator is connected to the terminals GEN. MAX. 50V. The matching impedance is 500 ohms. The output effect is 1.7 watts at 50 and 800 cycles and 1 watt at 10,000 cycles with a distortion of about 2%.

Power Supply

The instrument is designed for operation on 110, 127, 150, 200, 220 or 240 volt 50-60 cycle a-c.

OPERATING PROCEDURE

Before switching on the power, make sure that the instrument is adjusted to the line voltage available. The power switch is placed below the pilot lamp. Generally it is appropriate to ground the chassis of the Impedance Meter at the jack in the lower right-hand corner. Connect the unknown impedance to the terminals "Z" with leads as short as possible. (When measuring very high impedances, the leads - especially the upper one - are sensitive to hum. It may be necessary to enclose the impedance and its leads with a grounded shield). Then set the generator switch to "Z<150Ω" or "Z>150Ω" according to the expected value of Z.

Set the frequency switch "50-800-10,000 CYCLES" to the frequency required. If an external generator is to be used, set the switch to EXT. GEN. The external generator must be capacitively balanced referred to ground, and its chassis should be connected to the chassis of the Impedance Meter. As the generator is short-circuited when the switch "Z-R....R+C" is operated, its short-circuit current should not exceed 0.5 amp and its voltage should not exceed 50 volts so as not to damage the contacts in the switch.

Select an adequate sensitivity for the vacuum-tube voltmeter by means of the switch VOLTS. Set the switch "Z-R...R+C" of the vacuum-tube voltmeter to the positions Z and R respectively at the same time varying the decade resistors and the 10 ohm resistor until the deflection of the voltmeter is equal for both positions. The numerical value of the impedance can then be read on the decade resistor. Then set the switch to "D" and "φ" alternately while rotating the dial "φ" until the deflection of the voltmeter is equal for both positions. The dial "φ" now indicates the phase angle of the impedance. However, it is not possible to determine whether Z is inductive or capacitive. For this purpose use the switch positions "Z+C" and "R+C". Set the switch "C" to a value that will give a discernible difference between the voltages Z+C and R+C.

It is a matter of course that the setting of R is not changed.

Measuring with d-c load on the unknown impedance

As the decade resistor will generally not stand the d-c current which is required for Z, the d-c circuit must be established by shunting the winding examined with a known impedance Z_1. See fig. 8. In this case R_1 must be small in proportion to Z. In order to have perspicuous results choose for instance $Z_1 \gg Z$ or $Z_1 = Z$.

Accuracy of measurements

The built-in decade resistors are encumbered with an error (as previously mentioned it is 1% for the decade 10x0.1 megohm, and 0.2% + 0.1 ohm for the other decades) and a phase angle error which is within the calibration accuracy (0.3°) of the φ dial. The comparison between Z and R can be made with an accuracy of 0.2 to 0.3%. Therefore the total accuracy in determining the numerical value of Z will be better than 0.5% + 0.1 ohm for $Z < 100{,}000\Omega$. For $Z > 100{,}000\Omega$ it will be about 1%. If the phase angle measurement is to be reliable, the input impedance of the vacuum-tube voltmeter Z_{RV} (30 pF in parallel with 5MΩ) must be very great in proportion to the unknown impedance.

HOW TO REMEDY ERRORS

Interference from 50 cycle hum manifests itself in a regular hunting of the voltmeter needle when measuring with the generator at 50 cycles. This is due to interference between hum voltage and generator voltage. If such an error occurs, make sure that the chassis of the Impedance Meter is grounded and that the impedance is connected to the instrument by means of very short leads. (When measuring very high impedances, the upper lead is most sensitive to hum and it may therefore be necessary to envelope the impedance and its leads in a grounded shield) If, however, interfering hum should occur, the error is located as follows:

1) Connect a resistor of e.g. 1000 ohms directly to the binding posts Z and set the vacuum-tube voltmeter to the 0.1 volt range.

2) Set the generator switch to "Z>150Ω". Adjust the test voltage to 0.08 volt by means of the knobs OUTPUT and watch the amplitude of the hunting.

3) Set the generator switch to "Z<150Ω" and once more adjust the test voltage to 0.08 volt. Watch the amplitude of the hunting again. If the hunting is the same as before, the error is in the vacuum-tube voltmeter and may be due to defective insulation between cathode and grid in the type EF40 tube No. 4. If, however, the hunting has been halved, the error is due to 50 cycle hum on the anode voltage of the generator - possibly because of a defective electrolytic capacitor.

The violent and irregular fluctuations of the meter needle occurring when switching from one voltage range to another are due to various charging effects and not due to any error in the instrument.

CHANGE IN THE SENSITIVITY OF THE VACUUM-TUBE VOLTMETER

If after operating for a long time the vacuum-tube voltmeter indicates a too low voltage on the lower ranges, this may be due to aging in the tubes. A re-adjustment can be made with a potentiometer with slotted shaft located below the lower shelf to the left. This adjustment should also be made after inserting new tubes in the vacuum-tube voltmeter (EF40 No. 4 and 5).

REPLACEMENT OF THE TUBES OF THE GENERATOR AND THE POWER SUPPLY

can be made without any adjustment.

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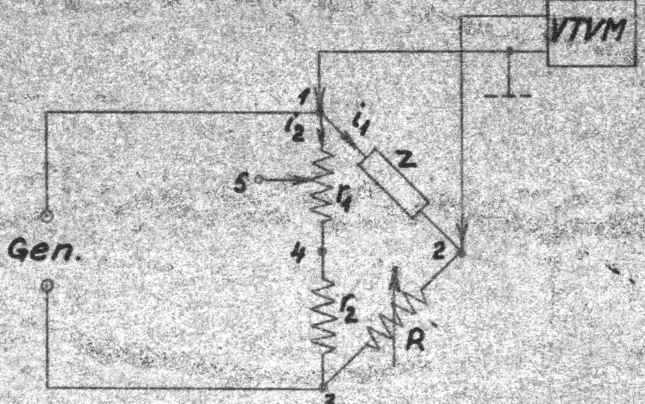


Fig. 1
Position "Z"

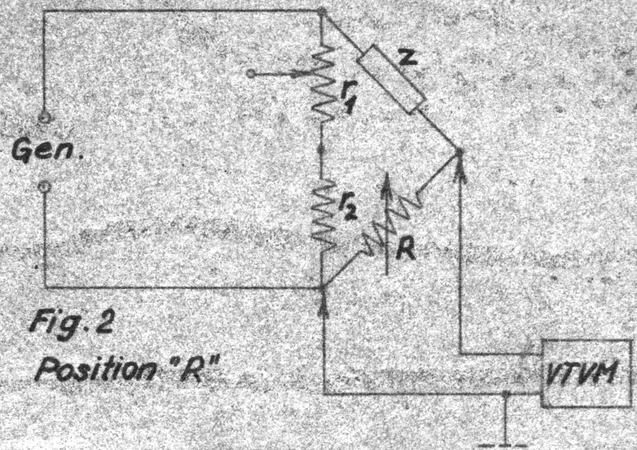


Fig. 2
Position "R"

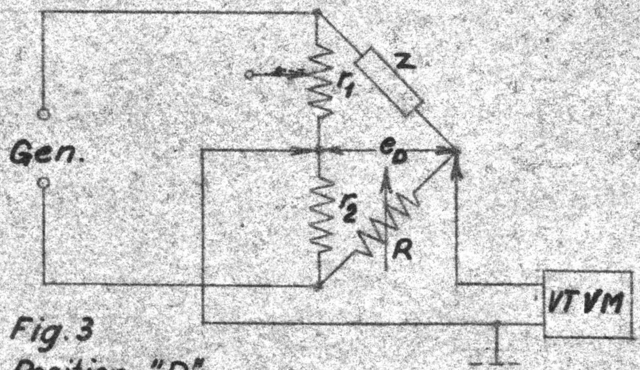


Fig. 3
Position "D"

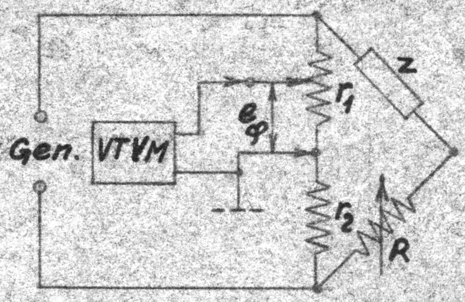


Fig. 4
Position "φ"

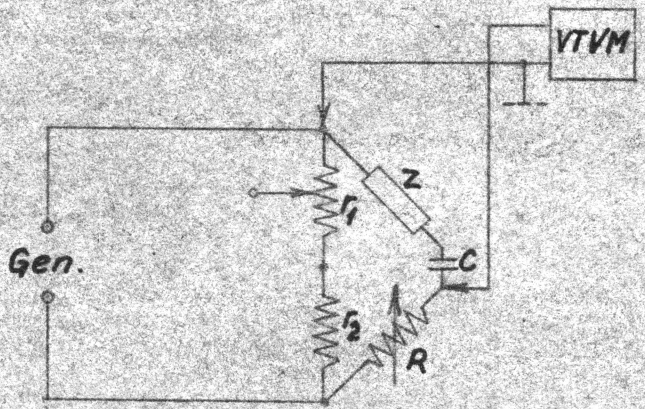


Fig. 5
Position "Z+C"

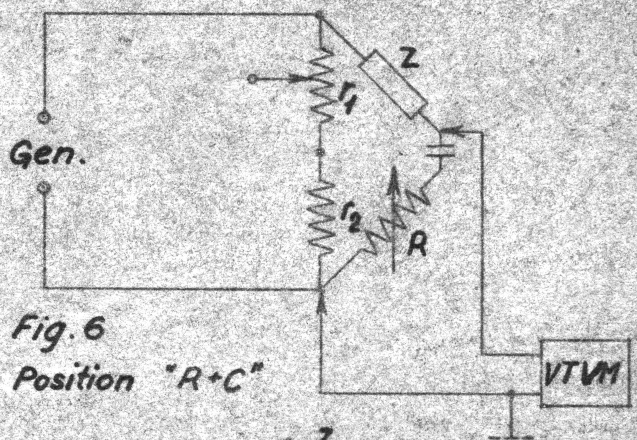


Fig. 6
Position "R+C"

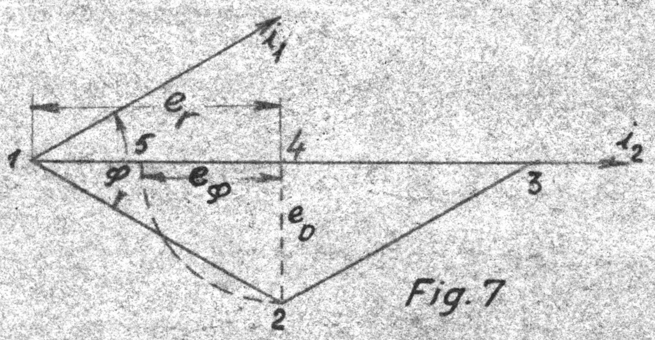


Fig. 7

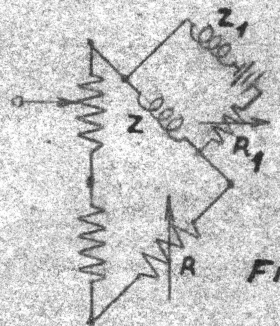


Fig. 8

Jmpedance Meter type GB 6
max. test voltage with sufficiently low distortion
at 500 and 800 cps

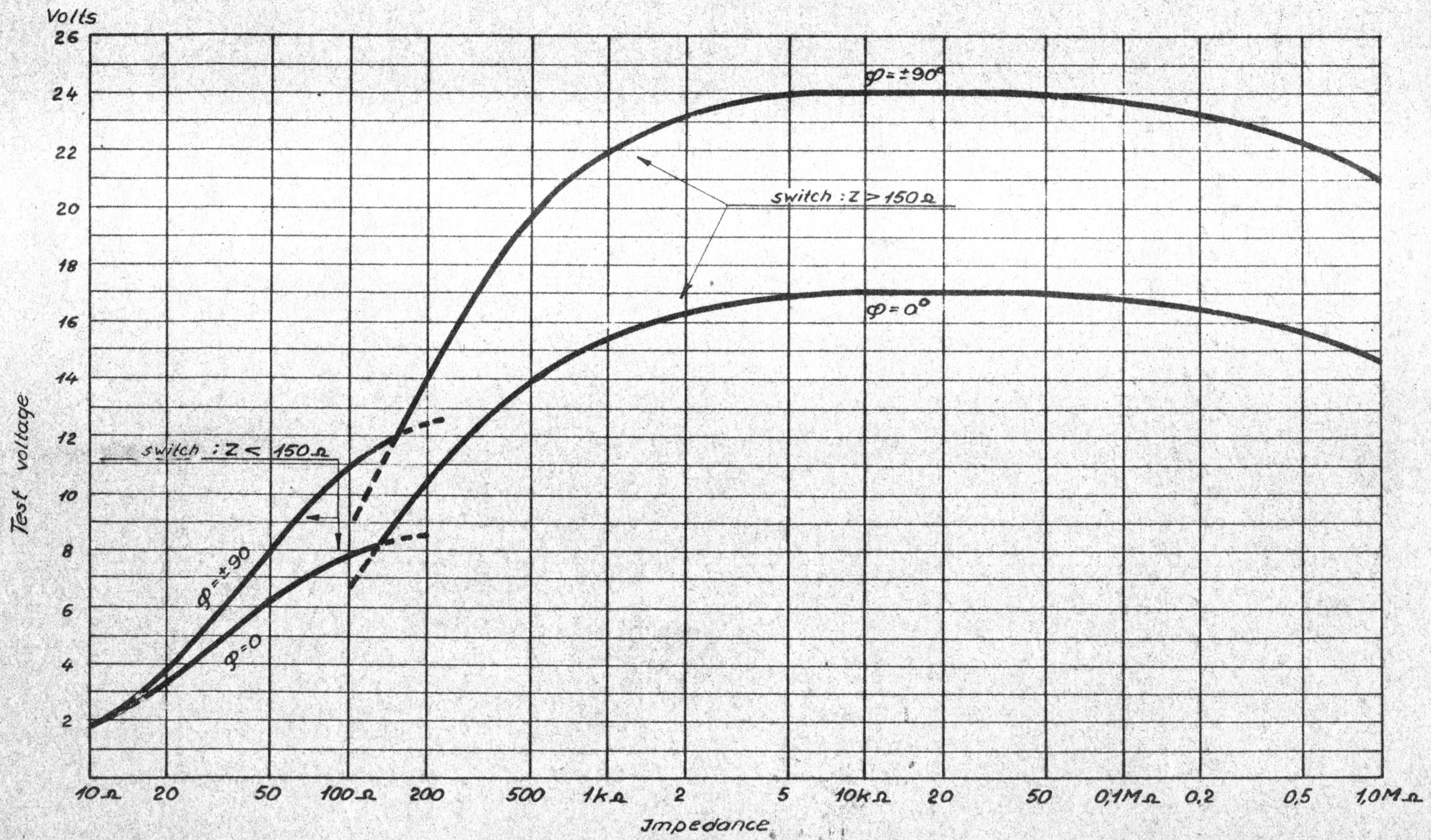
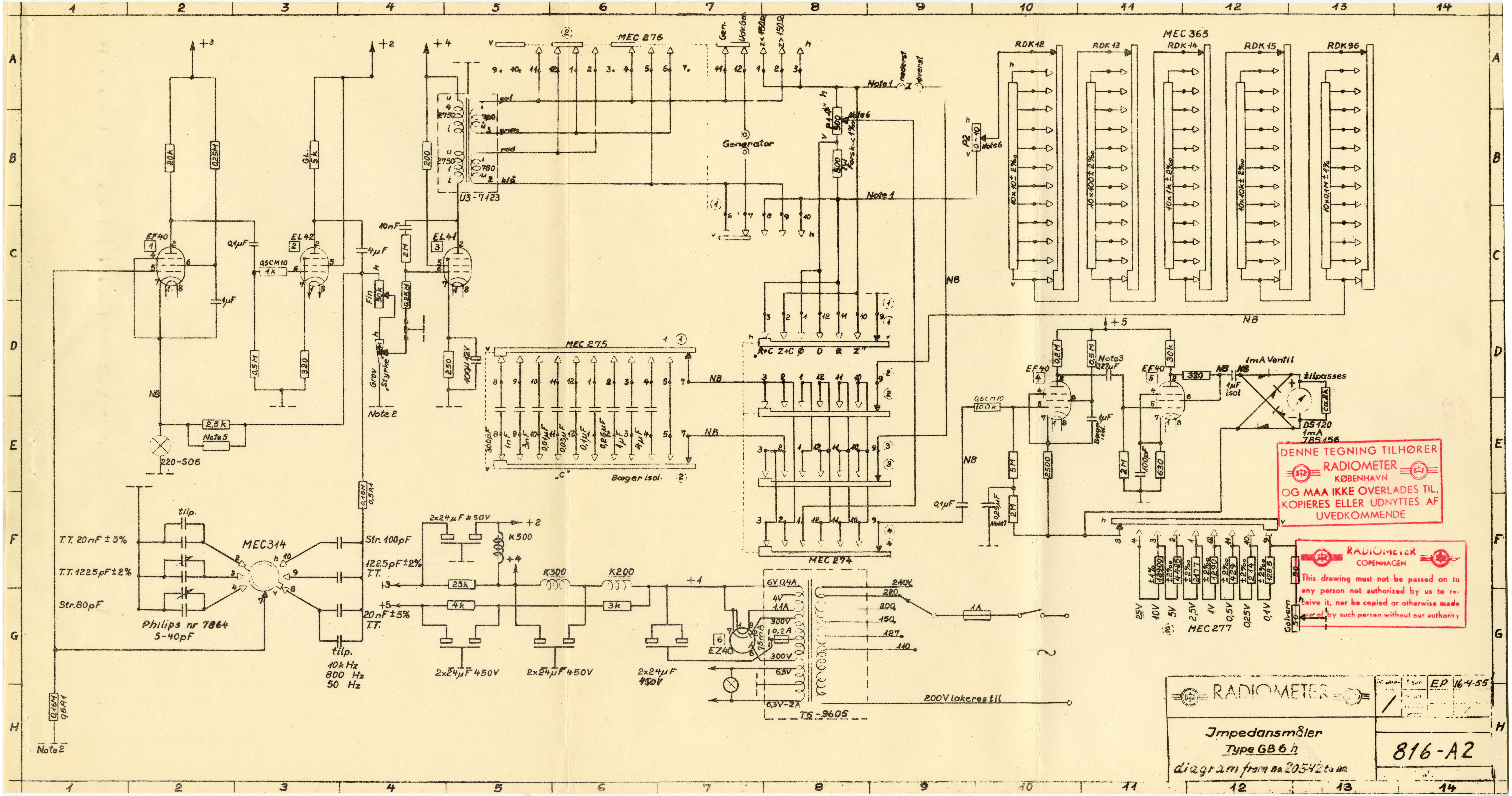


Fig. 9



DENNE TEGNING TILHØRER
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MEC 365
RDK 12
RDK 13
RDK 14
RDK 15
RDK 96
MEC 275
MEC 274
MEC 277
MEC 314
EF 40
EL 42
EL 41
EZ 40
U3-7123
T6-9605
Generator
Philips nr 7864
5-40pF
T.T. 20nF ± 5%
T.T. 1225pF ± 2%
Str. 80pF
Str. 100pF
200V lakeres til
1mA Ventil
tilpasses
Galvan
Bøger isol.
Note 1
Note 2
Note 5
Note 6