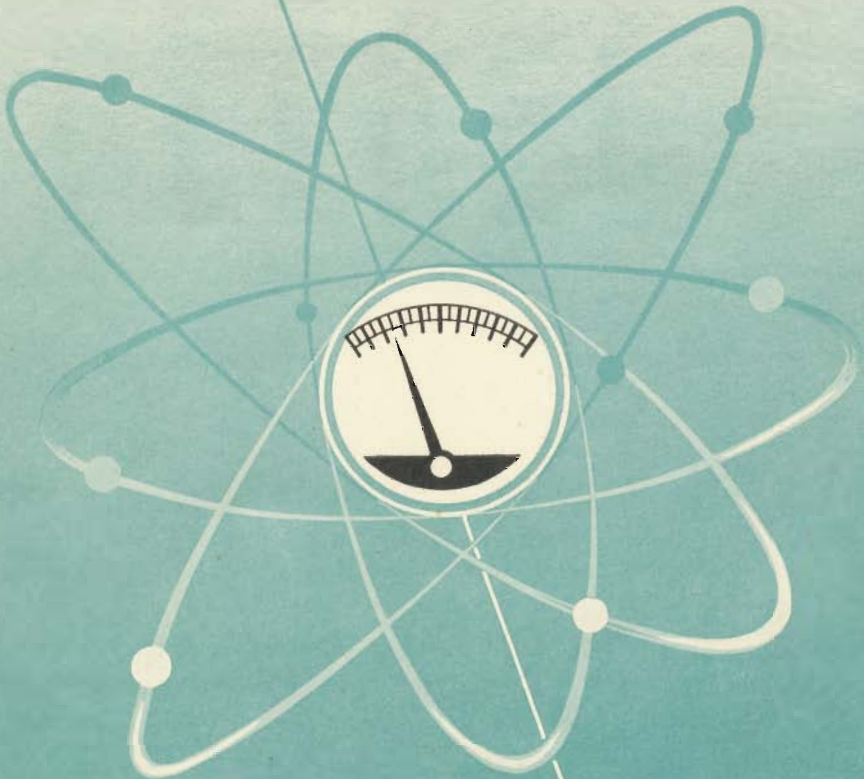

FB120

LABORATORY FOR ELECTRONICS

PEEKEL

1 ALBLASSTRAAT * ROTTERDAM * HOLLAND

INSTRUCTION FOR USE

of

Direct reading high precision phase-angle meter FB 120

Laboratory for Electronics

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Direct reading high precision phase-angle meter FB 120.

The phasemeter FB 120 is intended for the measurement of the phase angle between two voltages of the same frequency. The phase difference between the two waves is indicated directly on a meter.
The two input channels of the phasemeter can be used either symmetrically or asymmetrically so that it is possible to measure on balanced or unbalanced circuits to earth.
Due to the very high input impedance of both input channels the influence on the circuit to be measured is almost negligible.
The indication of the phase angle is independent of variations in the signal amplitudes and almost independent of harmonic distortion.
All adjustments and calibrations of the phasemeter can be carried out during measurement.
The instrument is equipped with an output for the connection of an external recorder, so that it is possible to record the vector relation of alternating voltages from 0 - 360 degrees.

Principle.

A functional diagram of the phase meter is drawn in fig. 1. The sinusoidal input signal at A - B Reference is, after being amplified inverted to a square wave signal. A control system incorporated in the input amplifier and square wave inverter takes care that the positive and negative fronts of the square wave signal coincide with the zero crossings of the original sinusoidal input wave independent of the amplitude of this signal.
The same circuit is employed for the φ channel. The two square waves at the outputs of the channels are further differentiated and than supplied to a trigger circuit.
The time interval, that exists between the two differentiated pulses of the two channels, is a function of the

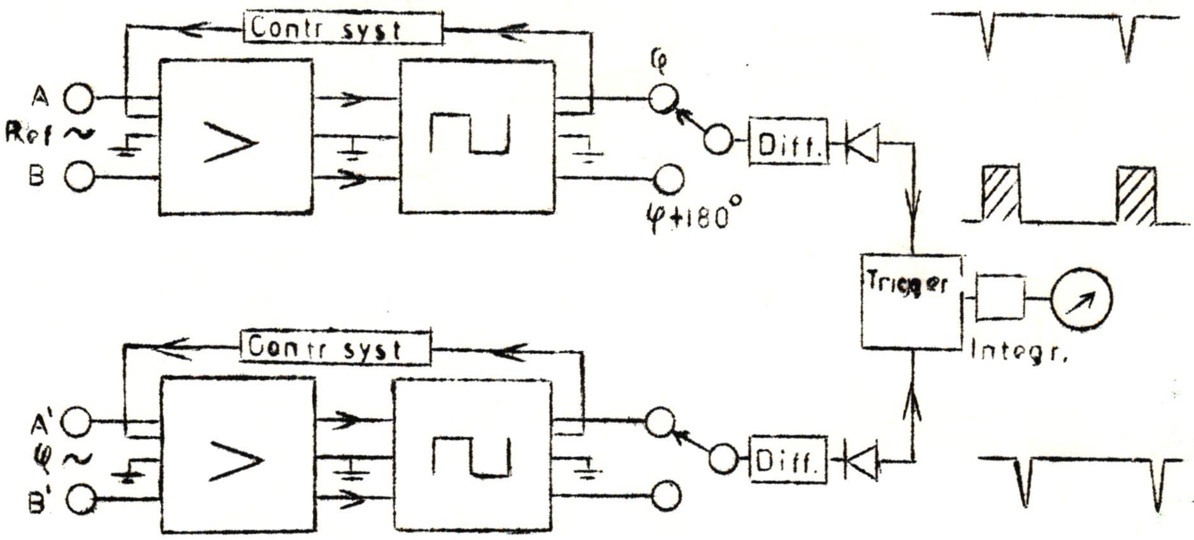


FIG.1

phase angle of the applied sinusoidal voltages at the inputs.
The output signal of the trigger circuit is a square wave signal which width is a linear function of the phase angle and after being integrated it is indicated by a vacuum-tube voltmeter.

Mains supply.

The phasemeter can be operated from an a.c. power source supplying 127 or 220 Volts. Selection of the proper operating voltage is made with the voltage selector on the rear of the instrument. The phase meter can be switched on by means of the toggle switch (fig. 2 K) at the frontpanel.

Earth connection.

In most cases it is necessary to earth the metal cabinet of the apparatus.

Adjustment of the phasemeter.

After a couple of minutes the apparatus can be adjusted. The switch directly below the moving coil meter at the frontpanel, fig. 2 knob E, is put in position "ZERO 1". Now with the knob A marked "ZERO 1" the meter is set zero. Further switch E fig. 2 is put at "ZERO 2" and again the meter is set zero but now with knob H, marked

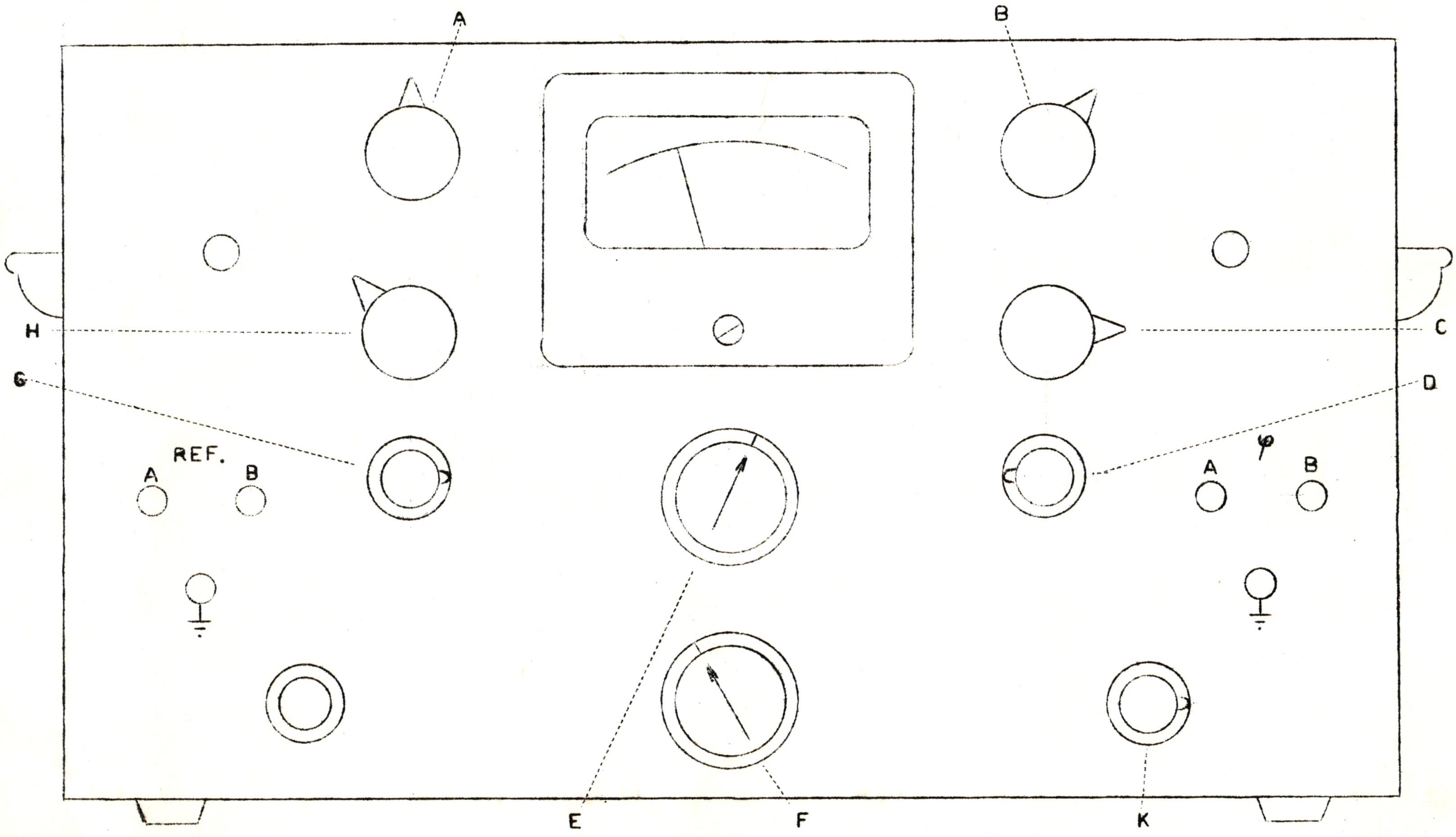


FIG.2

"ZERO 2". As both zero adjustments are not entirely independent of each other it is necessary to control "ZERO 1" again after adjustment of "ZERO 2" (fast adjustment by setting "ZERO 2" somewhat beyond zero).
Although for the first two positions just now described of switch E fig. 2 it is not necessary to have an input signal at the input channels, for the following positions however it is necessary to connect the input channels of the phasemeter to the measuring object so that a signal of correct amplitude exists at the input terminals, as during measurements.
At the next position of switch E fig. 2 "Full scale deflection" the meter is adjusted for full deflection with the knob marked with the same heading. The next step of switch E fig. 2 is marked "φ" and in this position a phase angle between 0 - 360° can be measured and if this switch is put at "φ + 180°" 180 degrees are added to the measured phase angle.
The last two positions of switch E fig. 2 marked "P ref" and "Pφ" are intended for the adjustment of the dynamic balance of the two input amplifiers. If both amplifiers are correctly adjusted the meter shows a deflection of 180°. When this is not the case the two screwdriver controls attainable through a hole at the frontpanel and marked "P ref" and "φ ref" ought to be adjusted until the meter shows a deflection of 180 degrees for both input channels. In order to be able to adjust this very precisely the switch F fig. 2 can be put at 135° - 180° or 180° - 225°.
It is necessary to do all the adjustments in the sequence of switch E fig. 2 and outlined above. So always start with the zero adjustments. During measurement all adjustments can be controlled with the help of the signals to be measured.

Phase angle measurements.

The switch E fig. 2 is put on "φ" and the range switch on 0 - 360° (knob F fig. 2).
To the inputchannel at the lefthandside of the frontpanel of the phasemeter the reference signal is connected and to the other input marked "φ" the phase shifted signal (see fig. 6).

Take care that both inputsignals are within the range of 50 mV - 10 Volts. Now the phase-angle can be read from the upper scale of the built-in meter and also determined in which half of a quadrant the phase-angle is found.

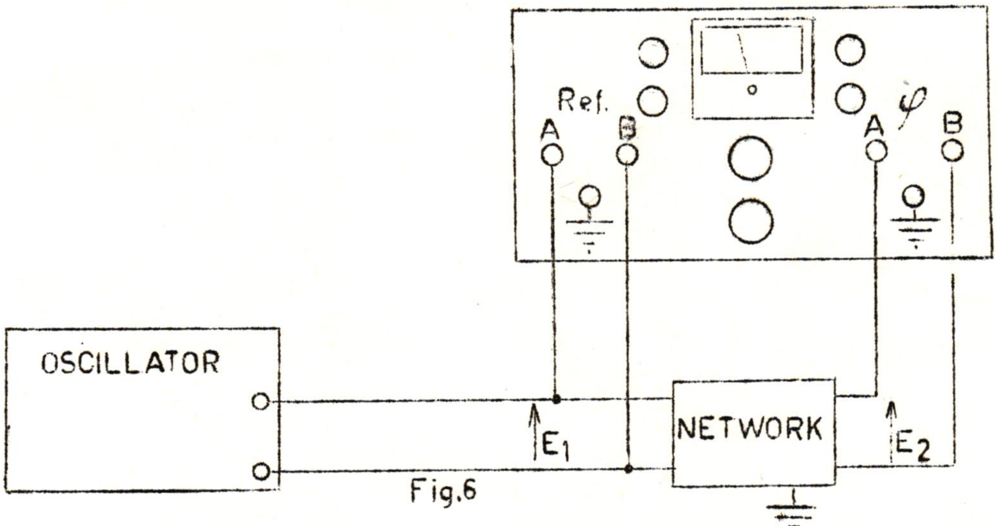


Fig.6

Further the range switch knob F fig. 2 is turned to the half of a quadrant in question, so that a more accurate reading is possible.
If the phasemeter is connected to the measuring object as shown in fig. 6 the phasemeter indicates the positive phase angle which E_2 leads in phase in respect to E_1. Suppose the phaseangle indicated is 270^0, than E_2 leads 270^0 in respect to E_1 or E_2 lags 90^0 in respect to E_1.
If one of the connections for instance the reference signal is reversed so that ref. A becomes ref. B and ref. B becomes ref. A, a phase shift of 180 degrees will occur in the phasemeter indication.
It is more practical to work with positive phase-angles as otherwise many mistakes can be made.
The network of fig. 3 is connected to the phasemeter and an oscillator of 100 c/s with an output voltage of about 10 Volts is used as the reference voltage. The phase-angle of this network is + 340^0 and will be indicated by the phasemeter. This means that $E\varphi$ leads 340^0 in respect to Eref or Eref lags 20^0 in respect to $E\varphi$. Note that both input channels are used asymmetrically so that one side of the input must be connected to earth.
It is also possible to measure the phase-angle over the

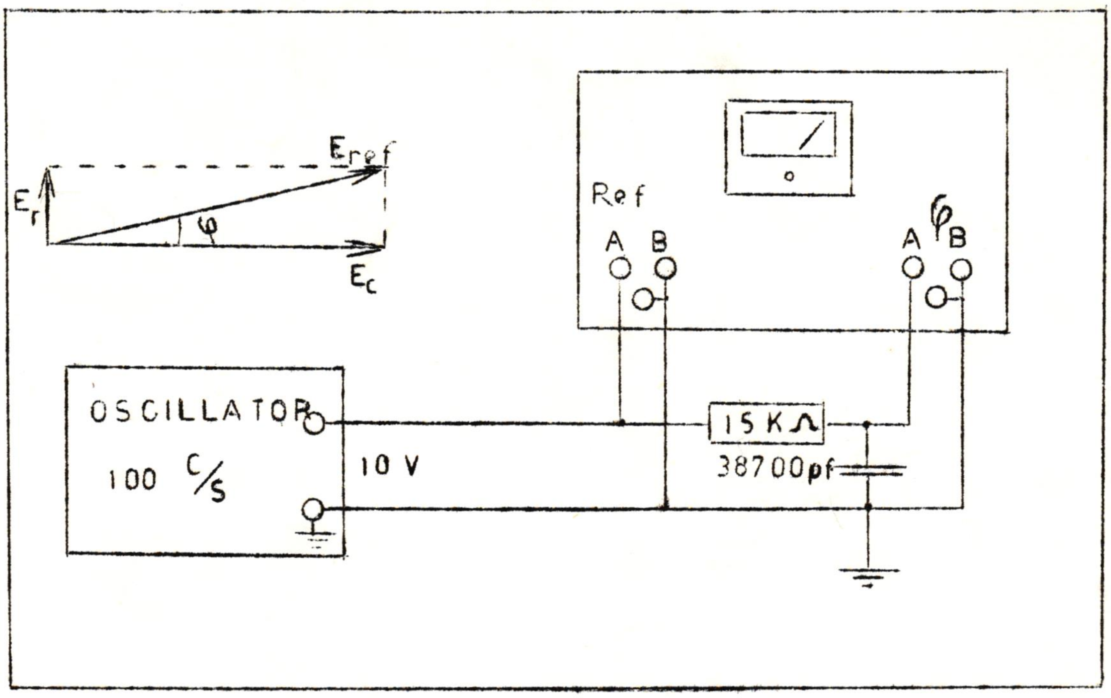

E_ref
E_r
φ
E_c
Ref
A B
φ
A B
OSCILLATOR
100 c/s
10 V
15 KΩ
38700pf

Fig. 3

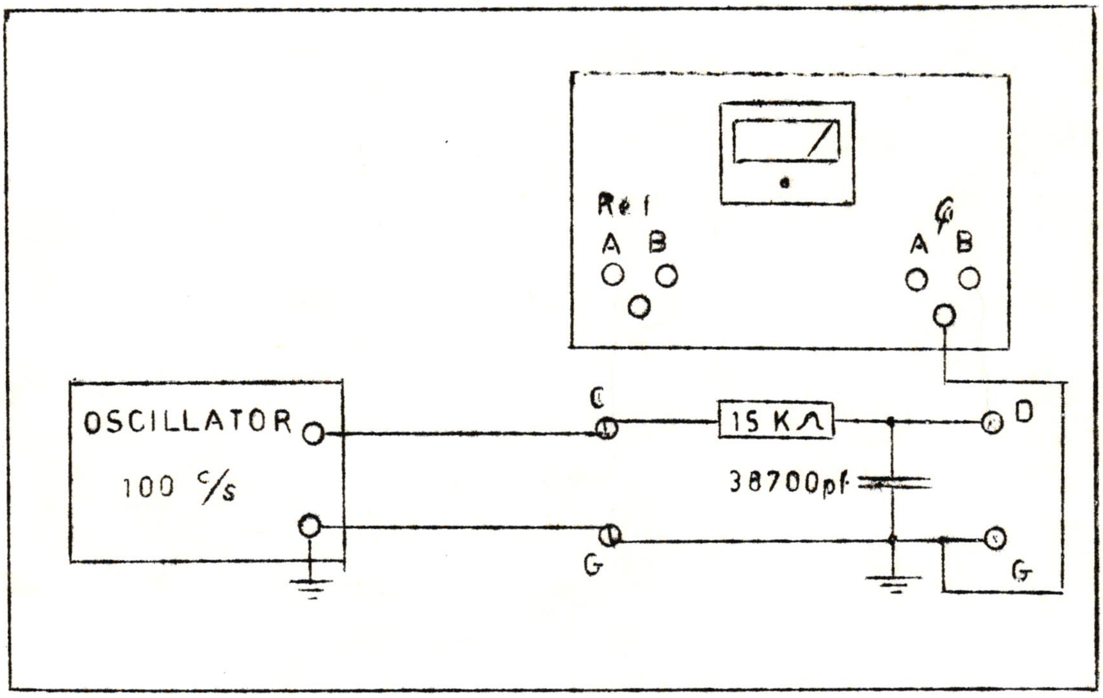

Ref
A B
φ
A B
OSCILLATOR
100 c/s
C
15 KΩ
D
38700pf
G
G

Fig. 4

the resistor of 15 000 Ohms and using again the supply voltage as reference signal.
In this case the indication of the phasemeter shall be +70°.
The same network is drawn in fig. 4 and the following phasemeter indications are possible by connecting the network in different ways to the phasemeter.

C connected to Ref. A
G connected to Ref. B
C connected to φ A
D connected to φ B
Indication of φ = + 70°
Indication of φ + 180° = + 250°

C connected to φ A
D connected to φ B
D connected to Ref. B
G connected to Ref. A
Indication of φ = + 270°
Indication of φ + 180° = + 90°

C connected to Ref. A
G connected to Ref. B
D connected to φ A
G connected to φ B
Indication of φ = + 340°
Indication of φ + 180° = + 160°

C connected to Ref. A
G connected to Ref. B
D connected to φ B
G connected to φ A
Indication of φ = + 160°
Indication of φ + 180° = + 340°

C connected to φ B
G connected to φ A
D connected to Ref. B
G connected to Ref. A
Indication of φ = + 20°
Indication of φ + 180° = + 200°

During measurements on high impedance circuits the input impedance of the phasemeter ought to be taken into account. Also take care of the capacity of the connection wires to the phase meter as this can cause an inaccurate phase measurement.

Toggle switches < 50 c/s.

As already mentioned the input amplifiers are directly coupled amplifiers and only at the input blocking condensers are incorporated in the circuit.
When small fluctuations in the signal to be measured are present, the time constant (or memory) formed by this condenser and high input resistance caused unstable phase meter readings.
To improve this the blocking condenser at the input can be made smaller by putting the toggle switches, one for each channel, from < 50 c/s to the other position (G and D fig. 2).
For measurements below about 50 c/s the switches ought to be put on "< 50 c/s".

Meter needle damping.

When the phase angle of very low frequencies has to be determined it is sometime necessary to damp the meter needle. With the aid of switch C fig. 2 it is possible to switch in two different meter needle dampings, together with this switch the time constant of the control system in the amplifiers is changed. Therefore it takes some time before the indication is stable. For very low frequencies below 1 c/s it is better to set the range switch to 0 - 360° and not to use the other phase angle ranges. Keep also in mind that the sensitivity of the input channels decreases for frequencies below 2 c/s (see the technical specification).

Measurements on symmetrical networks.

If the input circuits of the phase meter are used balanced to earth, the maximum a.c. voltage between one of the input terminals to earth may not exceed 10 Volts.

External meter or recorder.

At the righthandside of the phasemeter an output connection for an external meter or recorder is made.

In the phase range from 0 -360° an output voltage of 0 to approx. 8 Volts 1 mA is available on this terminals. To balance the built-in d.c. amplifier which supplies the output voltage to this terminals, a potentiometer control accessible through a hole at the back of the apparatus by a screwdriver is built-in.

Influence of distortion on the accuracy.

As outlined already the phasemeter compares the zero crossings of the reference signal with the zero crossings of the φ signal. When the original sinusoidal reference signal is distorted by passing for instance through an amplifier, the zero crossings can be shifted owing to the harmonics added to the signal.

Due to the special circuit employed in both input amplifiers the otherwise occurring fault in the phasemeter reading is highly reduced.

Let us suppose the ref. signal is sinusoidal and the φ signal is distorted only by second harmonics. In this case the shifts in the positive and negative zero crossings are opposite in directions (fig. 5). The amplifiers of the phasemeter are equipped with a special control circuit that shifts the zero line so much higher or lower, until the zero crossings are again symmetrically distributed (N^1 fig. 5).

To show how much this fault is reduced we have calculated the resulting fault in the phasemeter reading with and without control system for even harmonics in one input signal.

Without controlsystem in the amplifier and 10% second harmonics the maximum fault should be $\pm$ 6°, but with the control system the maximum fault is reduced to $\pm$ 0.6° and if there should be 10% of fourth harmonics, the remaining fault is only $\pm$ 1°.

The influence on the accuracy of the phase reading due to harmonics in the testsignal depends on the phase relation of these harmonics to the fundamental wave; therefore in the calculation above the maximum fault that can occur has been taken in account.

For even harmonic distortion of the testsignal, the control system incorporated in the amplifiers of this phase

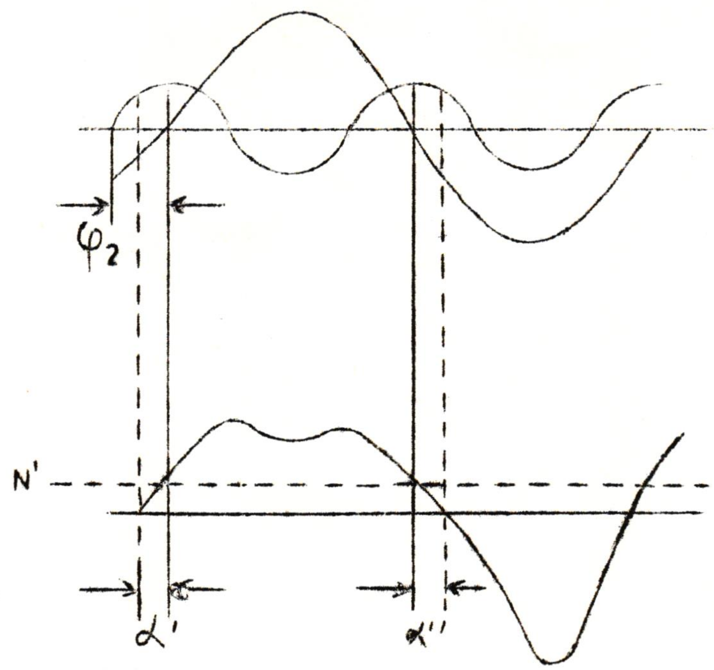


FIG 5

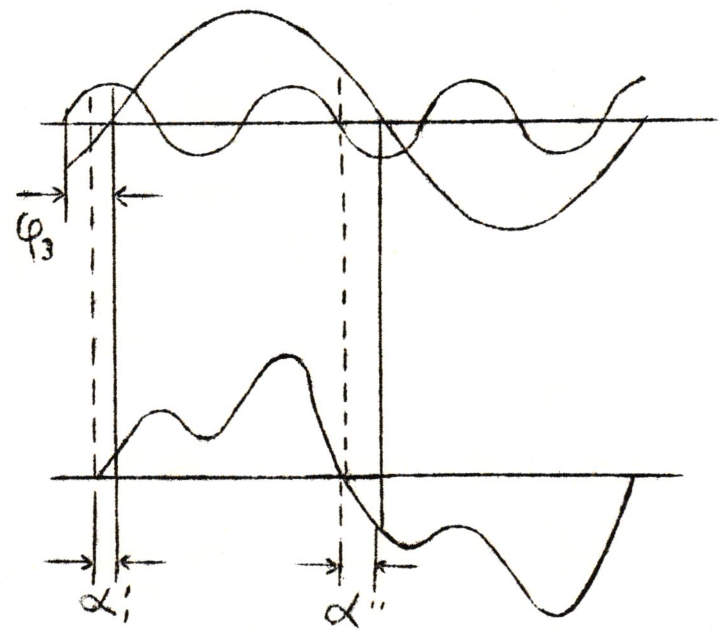


FIG 6

meter protected the user almost entirely for inaccurate phase measurements but for odd harmonics as will be shown below the control system does not work.

In fig. 6 the fundamental and third harmonic are drawn. As can be seen from this figure α' and α'' have the same sign and therefore the resulting fault $\Delta\varphi = \alpha' = \alpha''$.

In some cases the resulting fault caused by third harmonic content of the signal can be zero, depending on the phase relationship of this harmonic wave to the fundamental wave.

Below we have calculated the maximum fault that can occur in the phasemeter reading owing to harmonics in one signal applied to the phasemeter, the other signal is supposed to be sinusoidal.

$d_2 = 5\%$	$\Delta\varphi = \max. \pm 0.17^\circ$
$d_2 = 10\%$	$\Delta\varphi = \max. \pm 0.6^\circ$
$d_3 = 5\%$	$\Delta\varphi = \max. \pm 3^\circ$
$d_3 = 10\%$	$\Delta\varphi = \max. \pm 6^\circ$
$d_4' = 5\%$	$\Delta\varphi = \max. \pm 0.23^\circ$
$d_4' = 10\%$	$\Delta\varphi = \max. \pm 1^\circ$

$\underline{\varphi + 180^\circ}$.

If a phase angle is increased gradually from 0 to 360° the pointer of the phasemeter shall jumb to zero by passing 360°.

Around 360° and 0° sometime the indication can be unstable owing to the limited switchtime of the phase detector.

To avoid this the switch E fig. 2 can be put on "$\varphi + 180^\circ$" instead of "φ".

In this position 180° is added to the phase angle to be measured.

When e.g. 1° is to be measured the indication of the phase meter shall be in this case 181°.

Direct reading phase-anglemeter, type FB 120

Technical specification.

Frequency-range: 0.2 c/s - 50 000 c/s.

Phase-angle range: 0° - 360° and 0° - 45°; 45° - 90°; 90° - 135°; .... 315° - 360° without ambiguity.

Input impedance: 10 MΩ shunted by 25 pf on both input channels.

Input circuits: both input channels consist of differential amplifiers, which can be used balanced or unbalanced to ground.

Waveform of inputsignal: independent of even harmonic distortion of the inputsignal.

Inputsignalratio: accuracy is not effected by the ratio of input amplitudes ranging from 1 to 200 times.

Calibration: built-in possibility for calibration.

Input voltage: 50 mV - 10 Volts from 2 c/s to 50 000 c/s, the lower voltage limit increases to 1 Volt at 0.2 c/s.

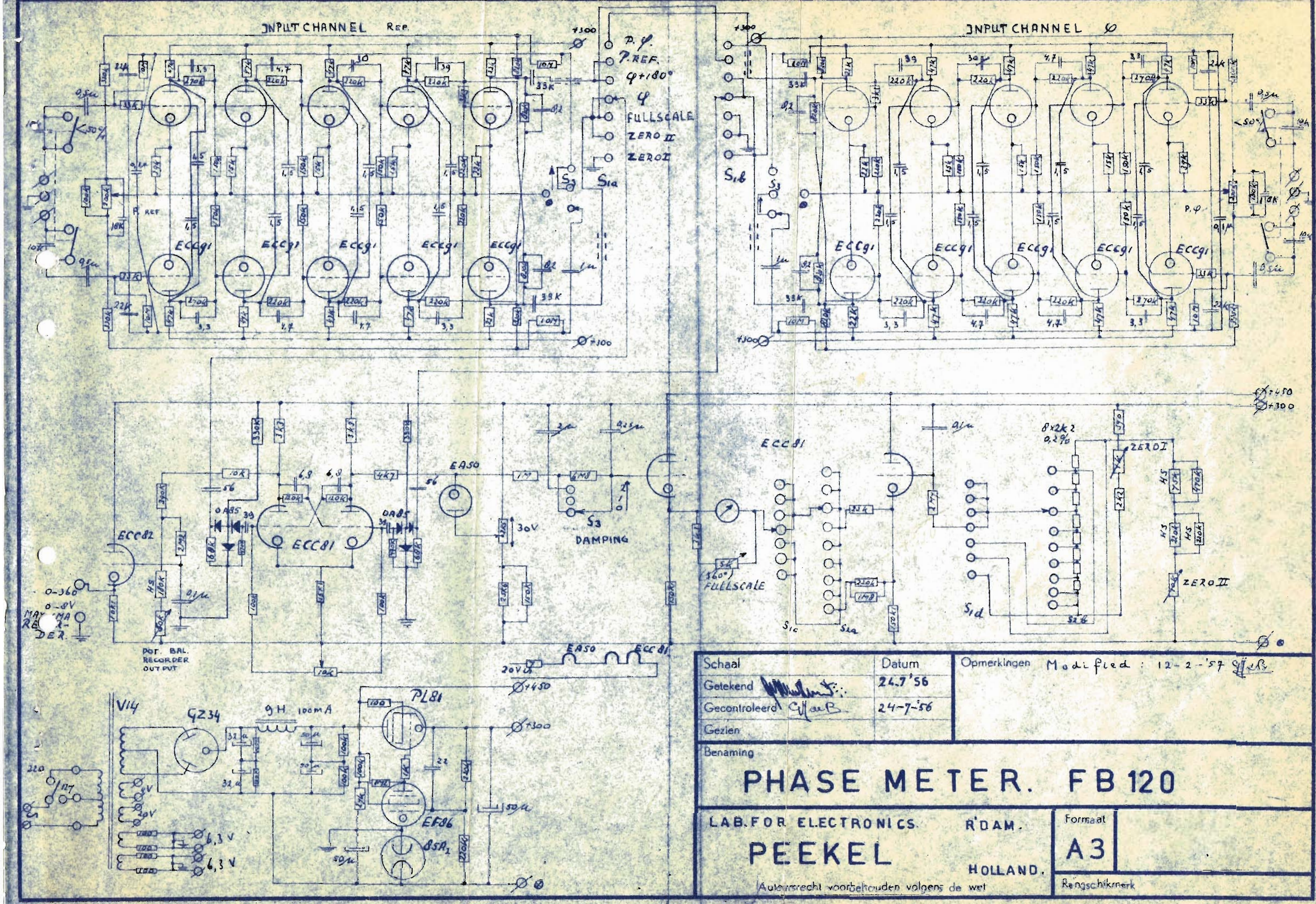
Accuracy: frequency-range 1 to 5000 c/s, accuracy $\pm 1^\circ$ (0.25 %); frequency-range 5000 - 10 000 c/s, accuracy $\pm 2^\circ$ (0.5 %); frequency range 10 000 - 50 000 c/s, accuracy decreasing to $\pm 10^\circ$ (3 %) at 50 000 c/s.
Below 1 c/s operation is possible if mean of meter readings is read.
The incremental accuracy is better than 0.2° or 0.05 %.

Output: A connection for an external meter or recorder is incorporated in the apparatus; d.c. output voltage for phase range 0 - 360°: 0 - approx. 8 Volts 1 mA.

Power supply: 127 or 220 Volts 40 - 60 c/s, 110 Watts.

Dimensions: 43 (length) x 22.5 (depth) x 29 (height) cm.

Tubes: 10 x ECC91 - 2 x ECC81 - ECC82 - EF86 - PL81 - 85A1 - GZ34 - EA50.



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Getekend	24-7-'56	
Gecontroleerd	24-7-'56	
Gezien		

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PHASE METER. FB 120

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