Introduction to Geiger Muller Tube

Purpose

To study the properties of GM tube such as plateau, dead time etc.
To investigate the statistical nature of counting experiments such as radioactive decay.

Background

See Experiments in Modern Physics by Melissinos (1996), sections 3.1 and 3.4 in chapter 5.

Warning

- ***Radiation can be harmful to humans and therefore precautions must be taken against undue exposure to it, and in the handling of radioactive materials.***
- ***Be careful of the mylar thin window of the GM tube, as it is easily damaged.***

Procedure

Arrange the experimental set up as shown below, and learn to operate different equipment correctly.

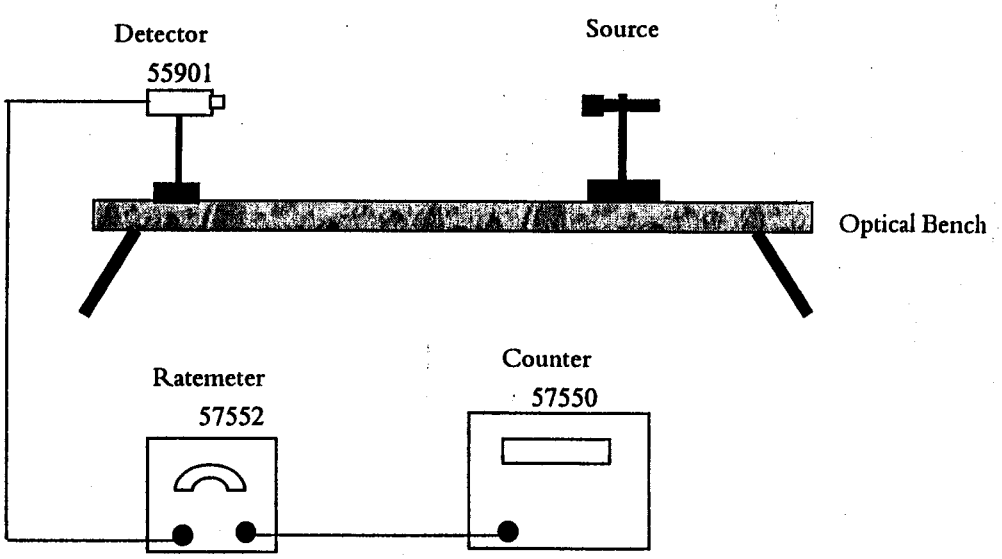

Fig. 1: Set Up for the GM Tube Experiment

Plateau

1. Begin with zero applied voltage (V_a) to the GM tube and increase V_a until counting is observed. At somewhere around 300 volts the counter should suddenly start counting. You are counting single nuclear decays! To determine these characteristics the voltage should always be increased because the GM tubes show hysteresis. Therefore, in case of a need to repeat a measurement, start at a lower V_a and then increase the voltage to the point of interest.
2. Then adjust the distance between the radioactive source and the entry window to GM tube so that a convenient rate of about 20 counts per second is obtained. Keep this distance fixed and record it. Here is a good time to explore. Take the source out. Do the counts stop? Can you detect cosmic rays (the background radiation)? The flux of cosmic rays at sea level is about one per minute per square centimeter. (Remember, you should be recording what you do and observe in your log book.)

3. Now, put the source back and try stopping the radiation with a paper, aluminum foil etc. What can you conclude from your observations. Remember the range of α is shorter than that of β, which is much less than that of γ.
4. Increase V_a in steps of 25 V and record the number of counts over a period of 100 sec. Do not exceed 740 V, otherwise the GM tube will be destroyed. Plot this data and find the threshold voltage and range of the plateau region of the GM tube.

Counting Statistics

5. Now, fix V_a at about the midpoint of the plateau region of the GM tube and do ten counts of ten seconds each. (Be sure that you are recording the total number of counts, not the number per second.) Using a pocket calculator, calculate the average of these numbers and their standard deviation. This standard deviation, called σ, is the error on a single 10-second count. It should be about equal to the square root of the average number of counts. Is it? This is the famous "square root of μ" law of statistics.

Gaussian Distribution

6. You can use the random decays from a radioactive source to generate a Gaussian distribution, as follows: make a histogram of a lot of values (at least 100) for one-second counts. Use a bin width of one for your histogram. (You can always combine bins later.) Don't write the values down, just enter them directly into the histogram. Does the distribution look Gaussian as shown in Fig.2? Draw in a "best-fit" curve by hand, and estimate the central value μ and the FWHM. Calculate σ = FWHM/2.35. Is this value consistent with the value expected from the square root of μ law?

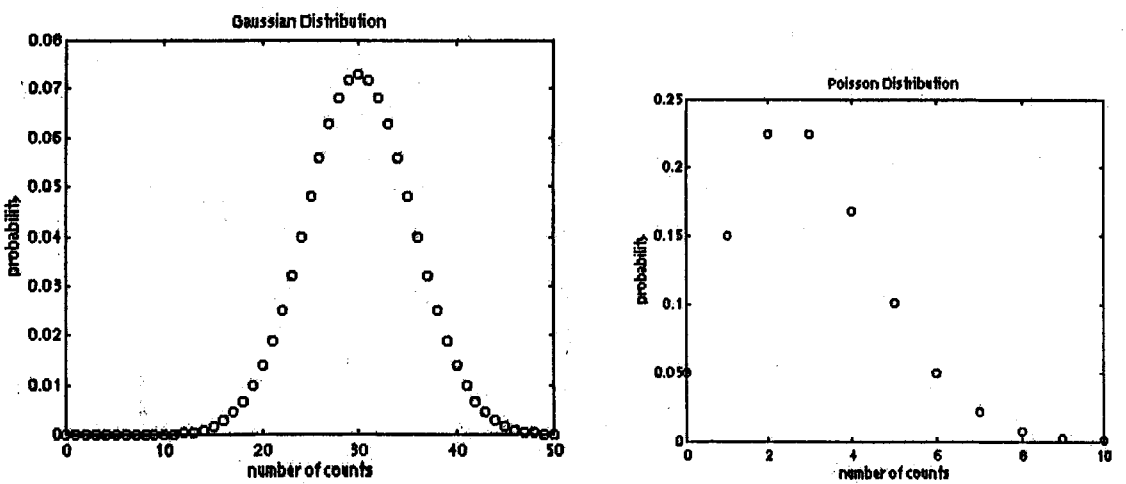

Fig. 2: Gaussian and Poisson distributions. The Gaussian distribution was calculated for an average value of x (μ) = 30, and the Poisson distribution for μ = 3. One can see the progression by which the Poisson distribution turns into the Gaussian for large x.

Dead time

7. To estimate the dead time (τ) of the GM tube, use both ^{137}Cs and ^{226}Ra sources as described on page 188 of Modern Physics by Melissinos (1996). (Remember, you should always try to reduce the random error in your measurements.)

Bonus Question

Can you think of any other experiment using this setup? Carry out the experiment if possible.

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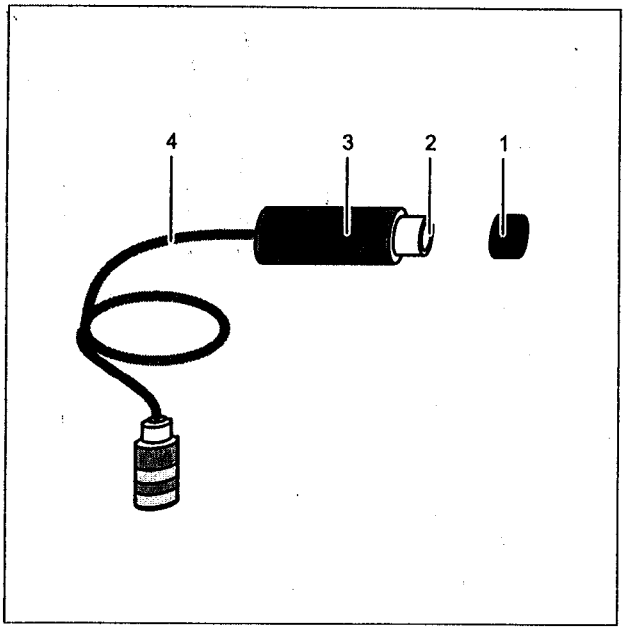

Instruction Sheet 559 01

End-window counter for α, β, γ Radiation and X-rays (559 01)

1 Window cap
2 Window
3 Geiger-Müller counter tube
4 Coaxial cable with plug

Important:

The window is fragile and can be easily damaged. Damage to the window will make the end-window counter inoperable.

- Do not touch the window.
- Always store the end-window counter with the protective cap attached.
- Remove the protective cap only when measuring.
- Remove and replace the cap carefully; do not turn it and do not block the vent hole.

The end-window counter can be damaged by self-maintained gas discharges if operated at too high a voltage.

- Do not exceed the maximum operating voltage of 600 V in a sustained manner.

1 Description

The end-window counter is a self-quenching Geiger-Müller counter tube with a very thin mica window (d = 12 - 15 µm). It is used to detect α and β radiation, and can also be used to measure γ and x-ray radiation.

2 Operation

Recommended display and counting devices with integrated supply voltage:

Counter P (digital display, loudspeaker)	575 45
GM-counter S (digital display)	575 46
Counter S (digital display, loudspeaker)	575 47
Digital counter (digital display, loudspeaker)	575 48
CASSY® computer interface device with GM box	524 033
X-ray apparatus (input: GM Tube)	554 811

- Place the end-window counter in the beam path (mechanically mount the apparatus e.g. using the large spring clip (591 21) and connecting rod (532 16) or the counter-tube holder from the STM equipment set RAD1 (588 855)).
- Connect the end-window counter to a suitable display and counting device with built-in voltage supply (approx. 500 V).
- Be sure to take the background effect into consideration for low counting rates.
- Take the dead time into consideration for high counting rates.

3 Technical data

Physical data:

Type:	Self-quenching Geiger-Müller counter tube
Gas filling:	neon/argon/halogen
Energy range:	≥ 3.5 MeV (α radiation) ≥ 50 keV (β radiation) ≥ 2.5 keV (γ and x-ray radiation)
Background effect in plateau	≤ 7 pulses/min (for screening with 50 mm Pb and 3 mm Al)
Length of active volume:	36 mm
Diameter of cathode:	13 mm
Diameter of anode:	1 mm

Window:

Material:	mica
Diameter:	11 mm
Mass per unit area:	1,5 ... 2 mg cm^{-2}
Reduction of range for α radiation:	approx. 1.4 cm through air

Electrical data:
(measured at 25 °C and 10^4 pulses/min with Sr-90/Y-90 source)

Cutoff voltage:	350-380V
Mean operating voltage:	approx. 500 V
Maximum permissible operating voltage:	approx. 600 V
Plateau length:	approx. 200 V
Relative plateau slope:	≤ 4 % / 100 V
Dead time:	≤ 90 ms
≥ expected service life:	$6 \cdot 10^{10}$ pulses
Working resistance:	10 MΩ

Cable:

Length:	55 cm
Thickness:	3 mm
Coaxial plug type:	Amphenol-Tuchel T 3162/1

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Gebrauchsanweisung
Instruction Sheet

575 52

Impulsratenmesser

Ratemeter

Das Ratemeter für Mittelwertsanzeige ist gut einsetzbar für Demonstrations- und Schülerversuche zur Messung der Impulsrate oder Frequenz einer statistischen oder periodischen Impulsfolge aus Zählrohr, Sinusgenerator, Mikrofon oder Fotoelement . Zusammen mit dem Digitalzähler (575 50, nicht mehr lieferbar) kann in definierten Zeitintervallen die Impulsrate digital erfaßt werden.

The ratemeter for mean value readings is suitable for demonstration and practical work with pulse rate or frequency measurements of statistical or periodic pulse trains from counter tube, sine wave generator, microphone or photocell. Combined with the digital counter (575 50 no longer available) it produces digital readings of pulse rates in defined time intervals.

1. Technische Daten

Anzeige der Impulsrate oder Frequenz als akustisches Signal oder als Mittelwert über ein Buchsenpaar auf Voltmeter oder als digitaler Meßwert über eine BNC- Buchse mit dem Digitalzähler .

Eingang für Wechselspannung: Frequenzbereich: 10 Hz (1 Hz) bis 10 kHz (Sinus)

Empfindlichkeit: 0,1 V(2V), max. 100V

Impedanz: 10kΩ, kapazitiv gekoppelt

Eingang mit Hochspannung für Zählrohr: Vorspannung: 0 bis 740 V in vier Stufen und kontinuierlich einstellbar

Zählbereich: 10^4 Imp/s

Lautsprecher: eingebaut, Lautstärke einstellbar

Ausgang für Digitalzähler: 5 V, TTL-kompatibel, kurzschlußfest, BNC-Buchse, 1 Signal (0,5 V, Ausgangslastfaktor F_Q=3) für jeden Impuls, Dauer je nach Zählrohrspannung, Länge des Zählrohrkabels und Frequenz: 60-150 µs

Ausgang für Voltmeter: 0-10 V, 3 mA, kurzschlußfest, Spannung proportional Mittelwert

Proportionalitätsfaktoren für Mittelwertsanzeige; bei Frequenzen: 1, 10, 100, 1000 Hz pro Volt

bei Impulsraten: 1, 10, 100, 1000 Imp/s pro Volt

Fehler: 3 % + Anzeigefehler des Meßinstrument

Anschlußspannung: 110/125/150/220/240 V, 50/60 Hz

Leistungsaufnahme: 10 VA

Sicherungen: T 0,08B (bei 220/240 V, Ersatz-Nr.69 804)
T 0,2B (bei 110/125/150 V, Ersatz-Nr. 69 808)

Abmessungen: 185 mm x 190 mm x 230 mm

Gewicht: 3,2 kg

1.Technical Data

Read-out of pulse rate or frequency as audible signal or as mean value via a pair of sockets for the voltmeter or as measured value for display on the digital counter via a BNC socket.

Input for a.c.: Frequency range:10 Hz (1 Hz) to 10 kHz (sinusoidal)

Sensitivity: 0,1 V (2V) max. 100 V

Impedance:10 kΩ, capacitatively coupled

Input with H.T. for counter tube: Bias voltage: 0 to 740 V in four stages , and continuously variable

Pulse rate: max. 10^4 pulses/s

Loudspeaker: built-in, with volume control

Output for Digital counter: 5 V, TTL-compatible (transistor transistor logic), short-circuit proof, BNC socket, 1 signal (0,5 V, output load factor F_Q=3) for each pulse,duration depending on counter tube tension, length of counter tube cable and frequency: 60-150 µs.

Output for Voltmeter: 0-10 V, 3 mA, short-circuit proof, voltage proportional to mean pulse rate

Proportionality constants for mean value; Frequencies: 1, 10, 100, 1000 Hz/Volt

Pulse rates: 1, 10, 100, 1000 pulses/s per Volt

Error: 3% +measuring error of instrument

Mains voltage: 110/125/150/220/240 V, 50/60 Hz

Power consumption: 10 VA

Fuses: T 0,08B (at 220/240 V, spare fuse Ref. No. 69 804)
T 0,2B (at 110/125/150 V, spare fuse Ref. No. 69 808)

Dimensions: 185 mm x 190 mm x 230 mm

Weight: 3,2 kg

2. Beschreibung

① Steckbuchse für Netzanschlußkabel
② Spannungswähler und Sicherungshalter
③ Netzschalter
④ Betriebsanzeigelampe
⑤ Ausgangsbuchsen zum Anschluß eines Voltmeters. Die Spannung (max. 10 V) ist proportional dem Mittelwert der Impulsrate bzw. Frequenz.
⑥ Wahlschalter für Proportionalitätsfaktoren zwischen Impulsrate (rechts für Eingang ⑧) bzw. Frequenz (links für Eingang ⑩) und der an den Buchsen ⑤ anliegenden Spannung.

2. Description

① Plug socket for mains lead
② Voltage selector switch and fuse holder
③ Mains switch
④ Pilot lamp for operational state
⑤ Output sockets for connection of a voltmeter. The voltage (max. 10 V) is proportional to the mean value of the pulse rate or frequency.
⑥ Selector switch for proportionality constants between pulse rate (right for input ⑧) or frequency (left for input ⑩) and voltage applied to the sockets ⑤.

⑦ BNC-Ausgangsbuchse zum Anschluß des Digitalzählers (575 50); 4-mm-Erdbuchse.

⑧ Eingangsbuchse für Zählrohrkabel (559 06 oder 559 07).

Achtung: Der Mittelleiter führt Hochspannung für das Zählrohr.

⑨ Stufenschalter und Einstellpotentiometer zur Einstellung der gewünschten Zählrohrspannung. Die Summe der angezeigten Spannungswerte gelangt zum Zählrohr.

⑩ Eingangsbuchsen für Wechselspannungen, deren Frequenz als Mittelwert gemessen werden soll.

⑪ Lautsprecher mit Abschwächer zur akustischen Anzeige der einzelnen Impulse.

Zum Lieferumfang gehört ein einpoliger BNC-Adapter.

⑦ BNC output socket for connecting the digital counter (575 50); 4 mm earth socket.

⑧ Input socket for counter tube cable (559 06 or 559 07).

Warning: The central wire supplies high voltage for the counter tube.

⑨ Step switch and adjusting potentiometer to set the required counter tube voltage. The total of the indicated voltage ratings arrives at the counter tube.

⑩ Input sockets for a.c. voltages the frequency of which is to be measured as mean value.

⑪ Loudspeaker with fader for acoustic indication of individual pulses.

The delivery includes 1 one-pole BNC-adapter.

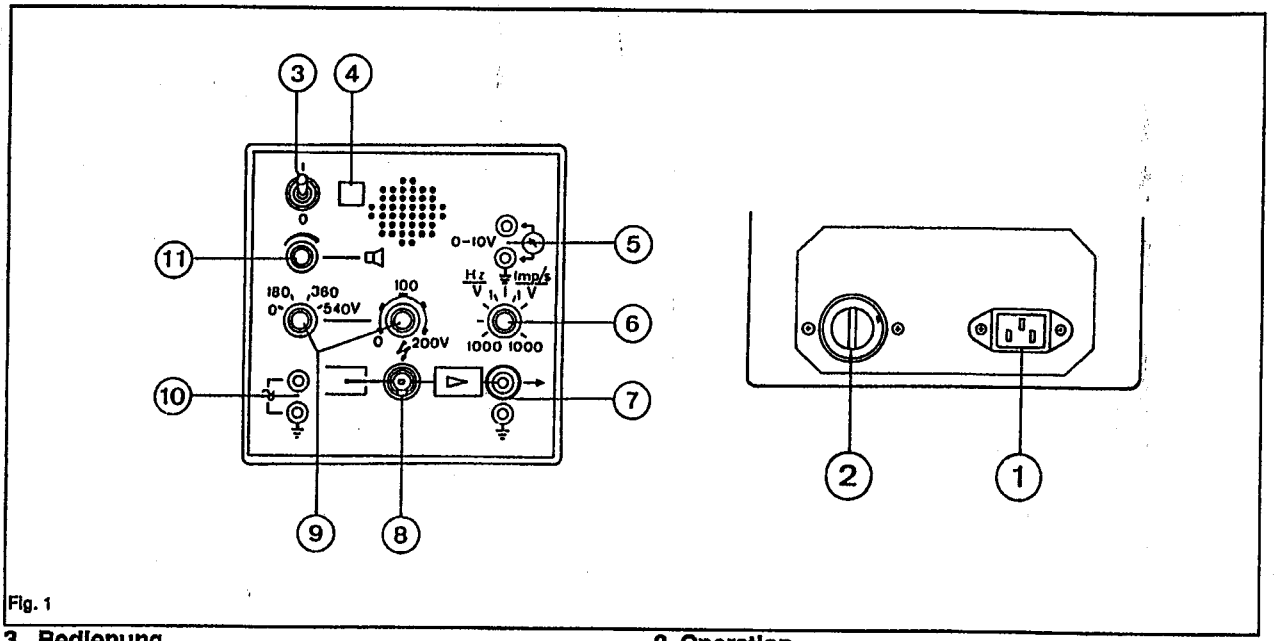

Fig. 1

3. Bedienung

3.1 Allgemeine Hinweise

Spannungswähler ② auf der Rückseite des Gerätes überprüfen; neben der weißen Markierung ⑬ muß der Wert für die ortsübliche Netzwechselspannung stehen (s. auch Fig. 3 in Abschnitt 4, Austausch der Sicherung).

Impulsgeber anschließen:

Zählrohr über Zählrohrkabel mit Eingangsbuchse ⑧ verbinden (siehe auch Gebrauchsanweisung für Zählrohre 559 00, 559 01 und 559 05).

oder:

Wechselspannungsquelle (Sinusgenerator, Mikrofon, Fotoelement) mit Eingangsbuchse ⑩ verbinden.

Gerät am Netz anschließen und mit Schalter ③ einschalten. Betriebsanzeigelampe leuchtet.

3.2. Ergänzung für akustische Anzeige und Mittelwertsbildung:

Geeigneten Proportionalitätsfaktor für den Mittelwert an Wahlschalter ⑥ einstellen und Voltmeter (Meßbereich z.B. 10 V -) mit Ausgangsbuchsen ⑤ polrichtig verbinden. Die dem Mittelwert proportionale Spannung darf 10 V nicht überschreiten.

Die am Eingang ⑧ anliegende Impulsrate oder am Eingang ⑩ anliegende Frequenz ergibt sich aus der am Ausgang gemessenen Spannung durch Multiplikation mit dem am Wahlschalter ⑥ eingestellten Proportionalitätsfaktor (rechts für Eingang ⑧, links für Eingang ⑩).

Mit Abschwächer ⑪ gewünschte Lautstärke einstellen.

3. Operation

3.1 General remarks:

Check voltage selector switch ② on the rear of the instrument. The local voltage rating should be placed near the white mark ⑬ (see also Fig. 3 in section 4, exchange of fuse).

Connect pulse generator:

Connect counter tube via counter tube cable with input socket ⑧(see also Instruction Sheet for counter tubes 559 00, 559 01 and 559 05),

or

connect a.c. voltage source (sine wave generator, microphone, photocell) to input sockets ⑩.

Connect instrument to the mains and switch in with the switch ③. Pilot lamp lights up.

3.2 Supplement for acoustic indication and RMS formation:

Set suitable proportionality constant for mean value indication on selector switch ⑥ and connect voltmeter (measuring range e.g. 10 V d.c.) to outlet sockets ⑤ observing correct polarity. The voltage proportional to the mean value must not exceed 10 V.

The pulse rate applied to input ⑧ or the frequency applied to input ⑩ results from the voltage measured at the output by multiplication with the proportionality constant set on the selector switch ⑥(right for input ⑧, left for input ⑩).

Adjust required loudspeaker volume by means of fader ⑪.

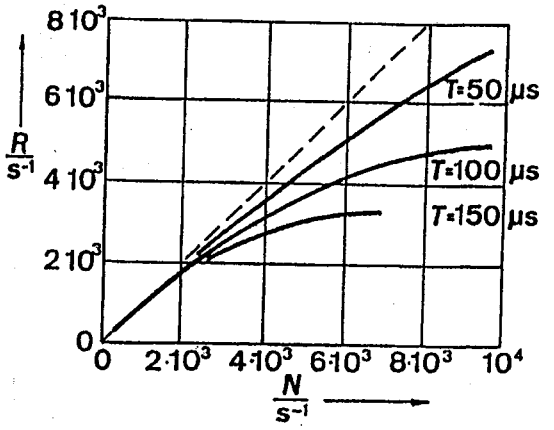

Fig. 2

3.3. Ergänzung für digitale Erfassung der Impulsrate:

Ausgang ⑦ des Ratemeters mit BNC-Eingangsbuchse des Digitalzählers (575 50) verbinden und geeignete Torzeit wählen (siehe auch Gebrauchsanweisung zu 575 50).

Die gemessene Zählrate R ist nur bei niedrigen Werten der in das Zählrohr eintretenden Strahlungsrate N proportional. Bei Zählraten über 2000 Imp/s treten als Folge der Totzeit T der Zählrohre von etwa 60 µs bis 100 µs größere Koinzidenzverluste auf (Fig.2). Die Totzeit, in der kein weiterer Impuls angezeigt wird, ist auch von der Länge des Zählrohrkabels und der Zählrohrspannung abhängig.

4. Austausch der Sicherung

Vor Sicherungswechsel Netzstecker ziehen!

Zum Austausch der Primärsicherung Geldstück in Schlitz ⑫ des Spannungswählers und Sicherungshalter ② stecken und so drehen, bis sich die "0" wie in Fig. 3 neben der weißen Markierung ⑬ befindet; die in dieser Stellung aus der Öffnung ⑭ federnd herausgedrückte Schmelzsicherung mit der Hand abfangen; neue Sicherung in Öffnung schieben und mit einem spitzen Gegenstand (Kugelschreiber oder Schraubenzieher) unter gleichzeitiger Drehung des Geldstückes in Schlitz ⑫ nach unten drücken.

Spannungswähler so einstellen, daß der darauf angegebene Wert für die ortsübliche Netzwechselspannung neben der weißen Markierung ⑬ liegt.

3.3 Supplement for digital reading of pulse rate:

Connect output ⑦ of ratemeter with BNC input socket of digital counter (575 50) and select suitable gate time (see also Instruction Sheet 575 50).

Only at low values the measured counting rate R is proportional to the counting tube. At counting rates above 2000 pulses/s larger coincidence losses will occur due to the dead time T of the counting tubes of approx. 60 µs to 100 µs (Fig. 2). The dead time, in which no further pulse is indicated, depends on the length of the counting tube cable and the counting tube voltage .

4. Exchange of fuse

Disconnect mains plug before exchanging fuse!

For exchanging the primary fuse, put a coin into slot ⑫ of the voltage selector switch and fuse holder ② and turn switch until the white mark ⑬ is near to position "0" as shown in Fig. 3. The fuse pushed out in this position by a spring is caught by hand, insert new fuse into opening ⑭ and press down by means of a pointed object, such as ball pen, screw driver or similar, at the same time turning and pressing down the coin in the slot ⑫.

Set voltage selector so that the local voltage rating appears near the white mark ⑬.

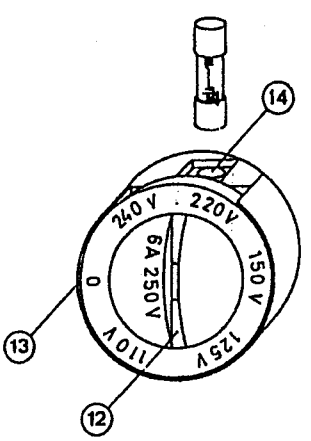

Fig. 3

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