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1. LUMINESCENT SCREENS

1.1 Choice of radiation-sensitive material

Several luminescent materials such as ZnS, lithium glass, sapphire and quartz are useful for beam detection (ref. 1, 2). Of these, ZnS is best suited to our purpose because of its sensitivity and low price.

The ZnS powder is sprayed with a clear binder on an aluminium foil. This foil is mounted on a quick-exchange holder. A net-work of pencil-lines is drawn on the screen for localising the beam (fig. 1). The total thickness is about 0,5 mm and the effect on beam blow-up of the ejected beam is moderate.

1.2 Lifetime of the screens

The screens become inactive after exposure to about 10^{17} protons/cm^2 (ref. 2). At Serpuchov this corresponds to about 1000 hours of continous operation, with ejection of the full beam each cycle. This is sufficient because the screen will be in operation only a small fraction of the time.

1.3 Flipping mechanism

A simple mechanism for flipping the targets in and out of the ejected beam is shown on fig. 2, 3 and 4. To prevent heating of the coils, the hold-current will be only a fraction of the initial current. The copper strips prevent gluing of the mechanism when the current is cut.

In SS 26 this mechanism will have to work in a field of 500 to 1000 Gauss. One has to check:
- that the mechanism will work properly in this field
- that the presence of the iron does not disturb the internal beam.

1.4 Illumination

The simplest way to illuminate the screens is to put a light bulb in the vacuum tank. The hot bulb will deteriorate the vacuum, however, and we will use a large low-power bulb to limit the temperature. By feeding it at 80 o/o of the nominal voltage, the lifetime of the bulb is almost infinite.

1.5 T.V. Camera

The T.V. installation is the responsibility of the IHEP. The camera will have to be placed as far as possible from the beam, to limit radiation damage. Consequently, the screen has to be viewed through a telelens. Provisions have to be made for U.V. radiation of all glass parts during the big shut-downs, to regenerate browned glass.

1.6 Possible mounting places

The ejected beam can be monitored in SS 24, 26 and 28. Position of the beam is measured in these sections with electrostatic pick-ups. We want an additional control in each of these sections. In SS 24 and 28 a beam-profile monitor will be mounted and, consequently, SS 26 is free for a luminescent screen.

The whole mechanism will be mounted on the right guard electrode of the electro-static pick-up (fig. 4). Spring contacts have to be made to the front plate for the electrical feed-troughs of the light bulb and the coils.

It can be helpful to have a second screen mounted on the mobile septum magnet to give an indication of beam position, when the electronics break down. This screen will have to be equilibrated to withstand the accelerations of the septum chassis.

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2. RADIATION MONITORING

2.1 Introduction

A preliminary report on this subject was made by Mr. Dijkhuizen (ref. 3). I thank him for some discussions and for the use of his documentation.

The general idea is to monitor the radiation in the vicinity of the kicker and septum magnets and deduce from it the beam losses on these units. The MPS team had the same problem, on a larger scale, a few years ago and, after some tests, it was concluded that an air-ionisation chamber (A.I.C.) was adequate for this purpose (ref. 4). Afterwards a system of 100 such chambers was mounted on the PS magnets (ref. 5). The results are satisfactory and, consequently, our system will be inspired by theirs.

2.2 The C.P.S. ionisation chambers

These chambers have the following characteristics:

air volume $I = 2{,}4$ liter
plate separation $d = 1$ cm
voltage $V_o = 2$ kV

These chambers are mounted on the upstream end of each main magnet. Consequently, the A.I.C. measure mainly the loss in the S.S. they face, because the other S.S. are shielded by the magnet units. These chambers were calibrated as well as possible (ref. 5). A pertinent result for our purpose is:

- beam energy	19 GeV
- beam loss on septum magnet 62 during slow ejection	10^{12} protons
- charge collected on A.I.C. downstream the S.M.	5.10^{-6} coulomb

Consequently, the charge collected per proton lost on the S.M. is:

$$Q_o \simeq 5.10^{-18} \text{ coulomb/proton}$$

2.3 Conversion rad-charge

The mean energy spent, by ionising radiation, to form one electron-ion pair in air is 34 eV. Consequently, the charge collected on the chamber is an absolute measure of the energy spent by the radiation in the active air volume and we can write the following relation:

$$1 \text{ rad} = 100 \text{ erg/g} = 1{,}8 \cdot 10^{12} \text{ ion pairs/l air}$$
$$= 3.10^{-7} \text{ coulomb/l air}$$

There is no simple relationship, however, between the number of protons lost and the radiation dose received by the air in the I.C. If the mean dose at a certain location is known, it can give an indication of the response of the I.C. to be expected.

2.5 Response-time of the I.C.

Oxygen and water vapor will trap the formed electrons, before they have moved very far, and form negative ions. The mean mobility of positive and negative ions in air at atmospheric pressure is:

$$\mu = 1{,}6 \ . \ 10^{-4} \ \frac{m}{sec} \Big/ \frac{V}{m}$$

for d = 1 cm and V_o = 2 kV, this gives a collection time:

$$t_{coll} = \frac{d}{\mu E} = 300 \ \mu \ sec$$

this will also be the maximum resolution of our observation system.

2.6 Approximate calculation of saturating conditions

We suppose the radiation occurs in a burst, which instantly ($t < 300$ µsec) creates an ion density of $+\rho_o$ and $-\rho_o$. We further suppose that each electron forms immediately a negative ion. If the space-charge forces are weak, the negative ion cloud will move uniformly to the anode and the positive cloud to the cathode. Recombination will take place until the two clouds are completely separated. For small losses we can write:

$$-\frac{d\rho}{dt} = \alpha \rho_o^2$$

The mean reaction volume is 1/2 of the volume of the chamber and this during 1/2 of the collection time:

$$-\Delta\rho = \frac{1}{4} \alpha \rho_o^2 t_{coll.}$$

with: $\alpha_{air} = 1{,}2 \ . \ 10^{+7} \ m^3/sec.coul$

$-\Delta\rho/\rho_o = 0{,}20$ (20 o/o loss)

$t \ coll = 300 \ \mu sec$

we find: $\rho_o \cong 2.10^{-4} \ coul/m^3$

and the charge collected on the chamber will be (without loss)

$$Q \cong \rho_o I = 5 \ . \ 10^{-7} \ coul$$

This corresponds to a loss of 10^{11} protons on the S.M. or 10 o/o of the normal beam.

At Serpuchov, the radiation per proton will probably be 3 times stronger, because of the higher energy, but the distance of the I.C. from the septum will be larger, if it is also mounted on the downstream magnet. So, we can expect comparable results. Anyway, we can play a bit on the distance septum-ionisation chamber.

Remark: The space-charge effect is the strongest at $x = d/2$, when the two ion clouds are just separated. The space-charge field is then, at saturation.

$$E_s = \frac{\rho_0 . d}{2\epsilon_0} \cong 10^5 \ V/m$$

This field reduces the collecting field to one half of its value. The effect on the loss is moderate, however.

2.7 Sensitivity

The sensitivity depends on the isolation resistance of the I.C. + cable + electronics. 10^9 ohm can certainly be obtained. If we want a time constant greater than 100 sec, the integrating capacitor has to be (fig. 16):

C min = 0,1 µF

A 10 mV rise will be above the noise level. This corresponds to 2.10^8 protons lost on the septum or about 0,5 o/oo of the normal beam. In favourable conditions, the sensitivity can be a factor ten better.

2.8 Conclusion

The CERN I.C. are of simple construction and have characteristics adequate for our purposes. They suffer, however,from losses in a high humidity environment. Consequently, I propose to copy their design with the following modifications:

- positive and negative plates will be mounted on separate ceramic insulators
- a resistor, dissipating about 5 Watt, will be incorporated to heat the chamber.

The resultant design proposal is shown on fig. 5.

2.9 Electronics

The electronic circuit is shown on fig. 7. The sensitivity is selected by the switches S_1. The radiation current is integrated during the cycle and at the end of each cycle the capacitors are discharged through S_2. The voltage on the capacitors is compared with a ref. voltage and if it exceeds the limit set by R_1 an alarm is triggered. S_4 resets the alarm. N_1 is a neon lamp, which protects against over-voltages.

In order to know what happens exactly, one has to watch the voltage on the integrating capacitor. This is best done with a special scope. This scope can be quite simple and cheap, but must have the following characteristics:

- a large very-long-persistence screen.
- a vertical D.C. channel
- a 10-second time base
- intensity modulation

The moments of ejection are marked by intensity modulation of the scope.

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3. TARGETS

3.1 Introduction

It is of interest to know the profile of the internal beam. The simplest way to measure this is to intercept part of the beam by mechanical means and to measure the intensity of what is left of the beam.

For this purpose the standard target actuators are used at the CERN PS. For us, however, this would create many complications, because (ref. 6, 7, 8):

- the actuators are not available and difficult to reproduce
- the commanding electronics are complicated and not available either
- the use of these targets is rather complicated for our purpose.

In this report a simple mechanism will be proposed, which is better suited to our needs.

3.2 Proposal for a Serpuchov target

The proposed target mechanism is shown on fig. 8. An aluminium rod, some 4 mm thick sweeps through the beam in a circular motion. Its rest positions are on either side of the beam at injection. The distance between these two rest positions is 20 cm. The rod traverses this distance in 200 steps of 1 mm, commanded by a stepping motor. The whole traversal takes 1 second. The movement is sufficiently linear in the center, where the beam is intercepted.

The stepping motor is commanded by an up-down counter, which does the position-book-keeping. If counts are missed the motor will touch one of the end positions (a strong spring), which will assure a correct starting position for the next traversal. A micro-switch will indicate that something went wrong. The whole mechanism has to be lubricated with M_oS_2 to prevent gripping.

3.3 Specifications for the stepping motor

No vacuum feed-through exists with characteristics adequate for our purpose. Consequently, the motor has to be placed in the vacuum. The "Superior Electric Company" makes a series of stepping motors, guaranteed to work in vacuum up to 10^{-6} torr. They make 200 steps per revolution. The target arm makes 200 steps while turning through an angle of 60 degrees. Consequently, a gear ratio of 1 to 6 has to be provided between the motor shaft and the target arm.

The whole mechanism will present an inertial couple on the motor shaft of about:

$$I_o \simeq 500 \text{ g . cm}^2 \simeq 3 \text{ oz - in}^2$$

The smallest motor of the series can take 25 oz - in^2. So, we take this type:

Slo - syn motor SS 25 V - 1001

It would be useful to order two units immediately, to make some preliminary tests on the dynamical precision obtainable with these motors.

When the motor is not moving, the voltage must be reduced in order to limit the dissipation. Just enough must be provided to keep the position fixed.

3.4 Timing and display

The timing is coupled to the ejection moment. The read-out will be on an oscilloscope screen, via the computer. The display will show the intensity left in the machine (measured with the pick-up electrodes) in 30 successive steps of 1 mm. The ejection will be inhibited but the normal ejection-moment will fall between steps 15 and 16. The position of the target at this moment can be adjusted between r = -50 and r = +50 mm. The complete procedure takes two machine cycles (traversal in either direction). The circuitry to do all this is shown on fig. 9.

References

LUMINESCENT SCREENS

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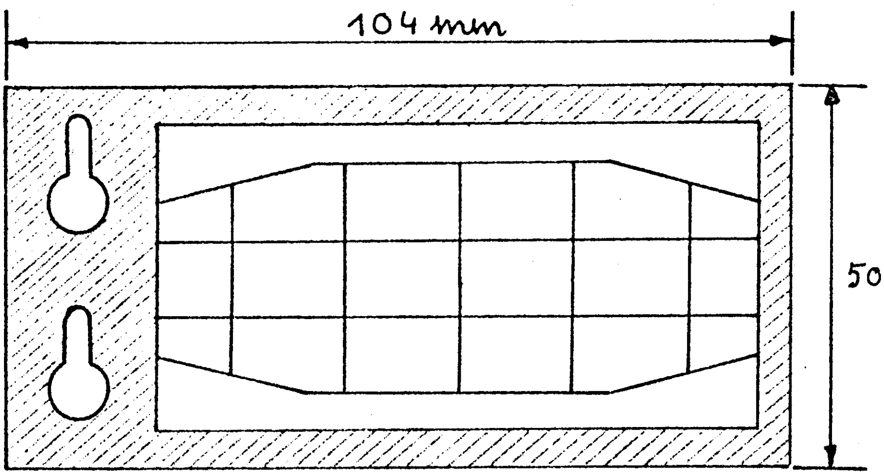

Fig. 1. Quick-exchange screen.

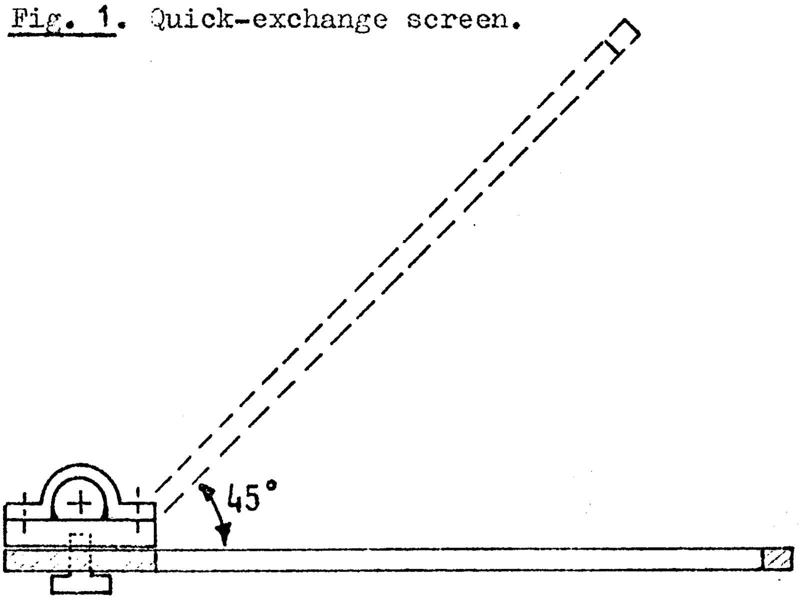

Fig. 2. Screen in rest (and work) position.

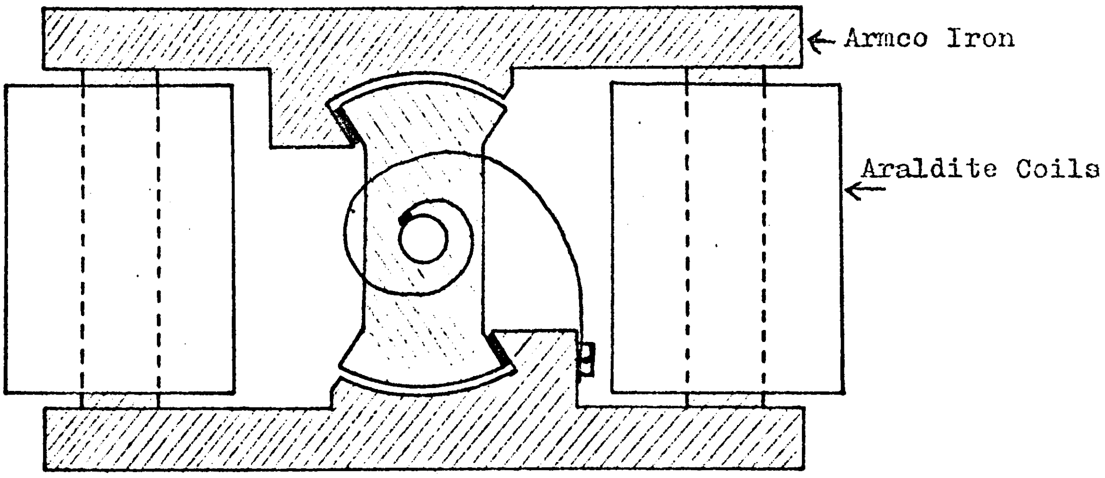

Fig. 3. "Flipping" mechanism in work position.

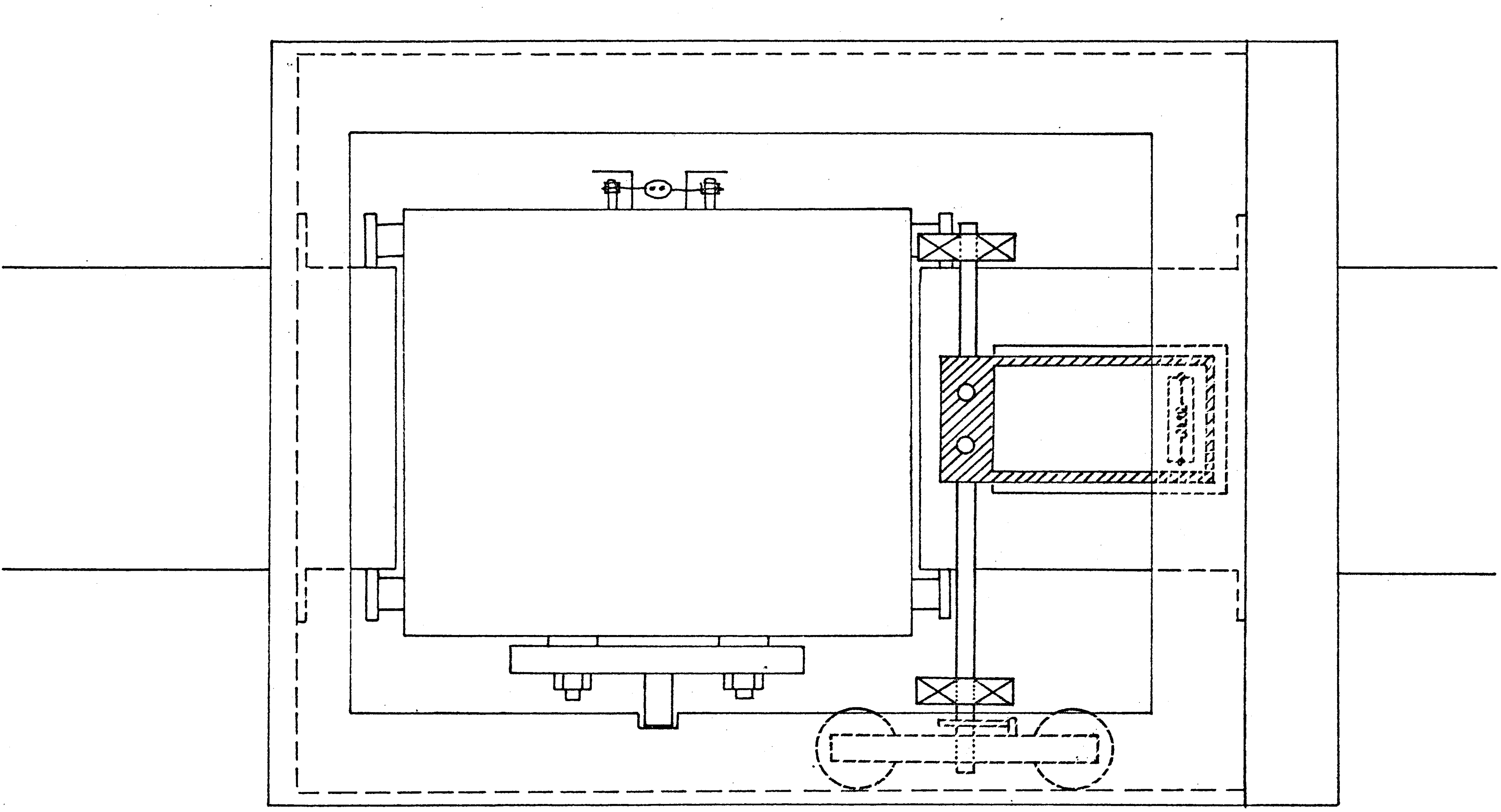

Fig. 4. Screen and "flipping" mechanism mounted in tank in SS 26.

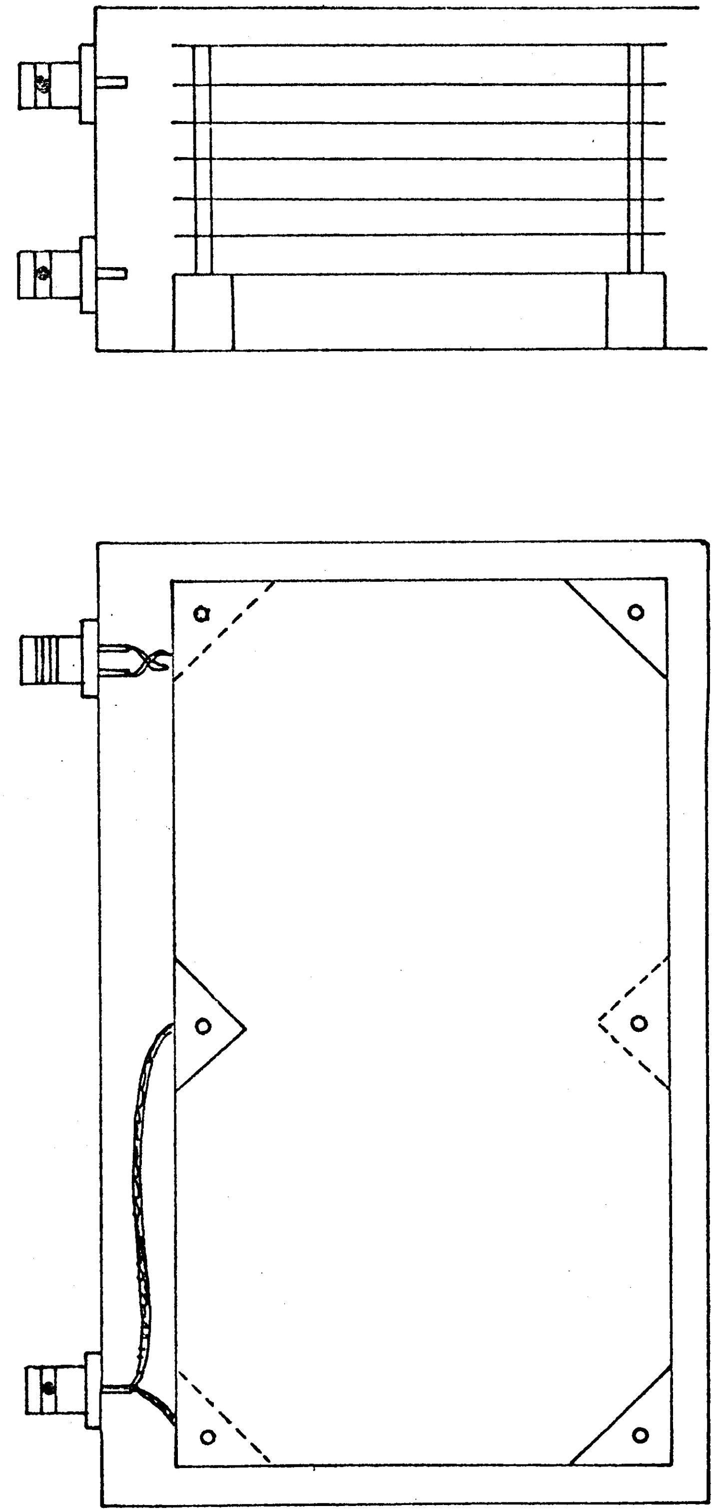

Fig. 5. Air ionisation chamber.

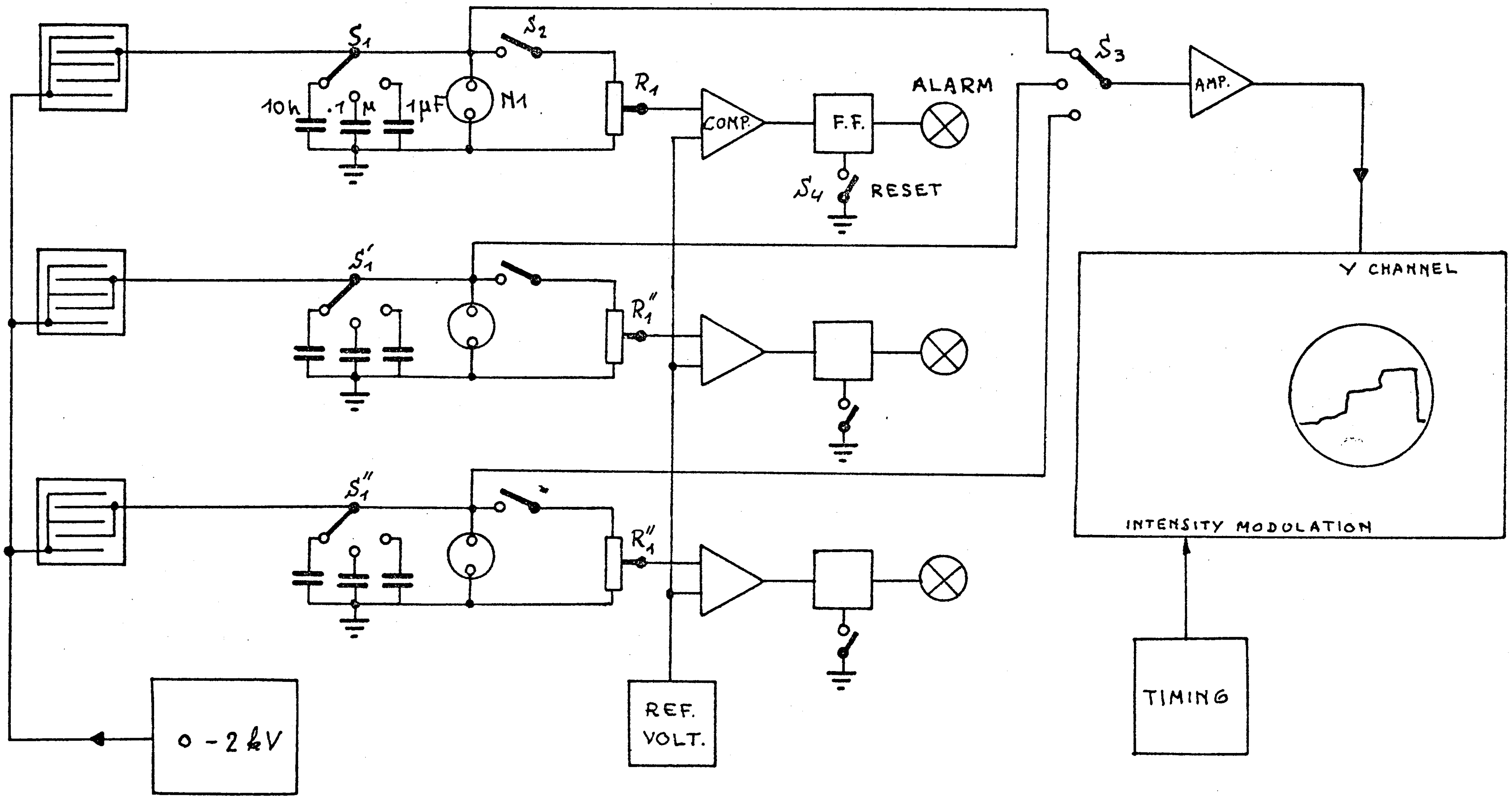

Fig. 6. Radiation-monitoring circuit.

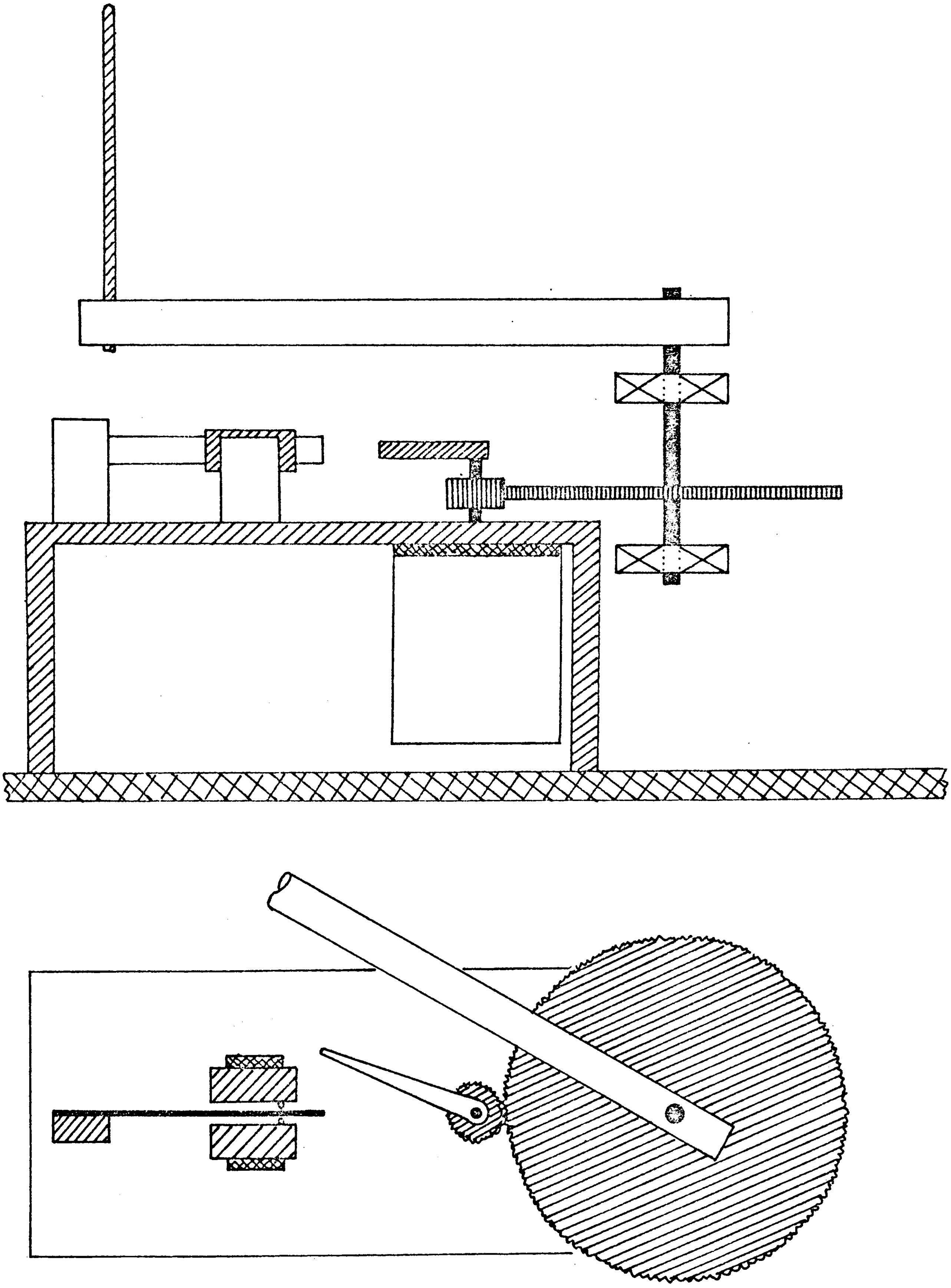

Fig. 7. Target mechanism.

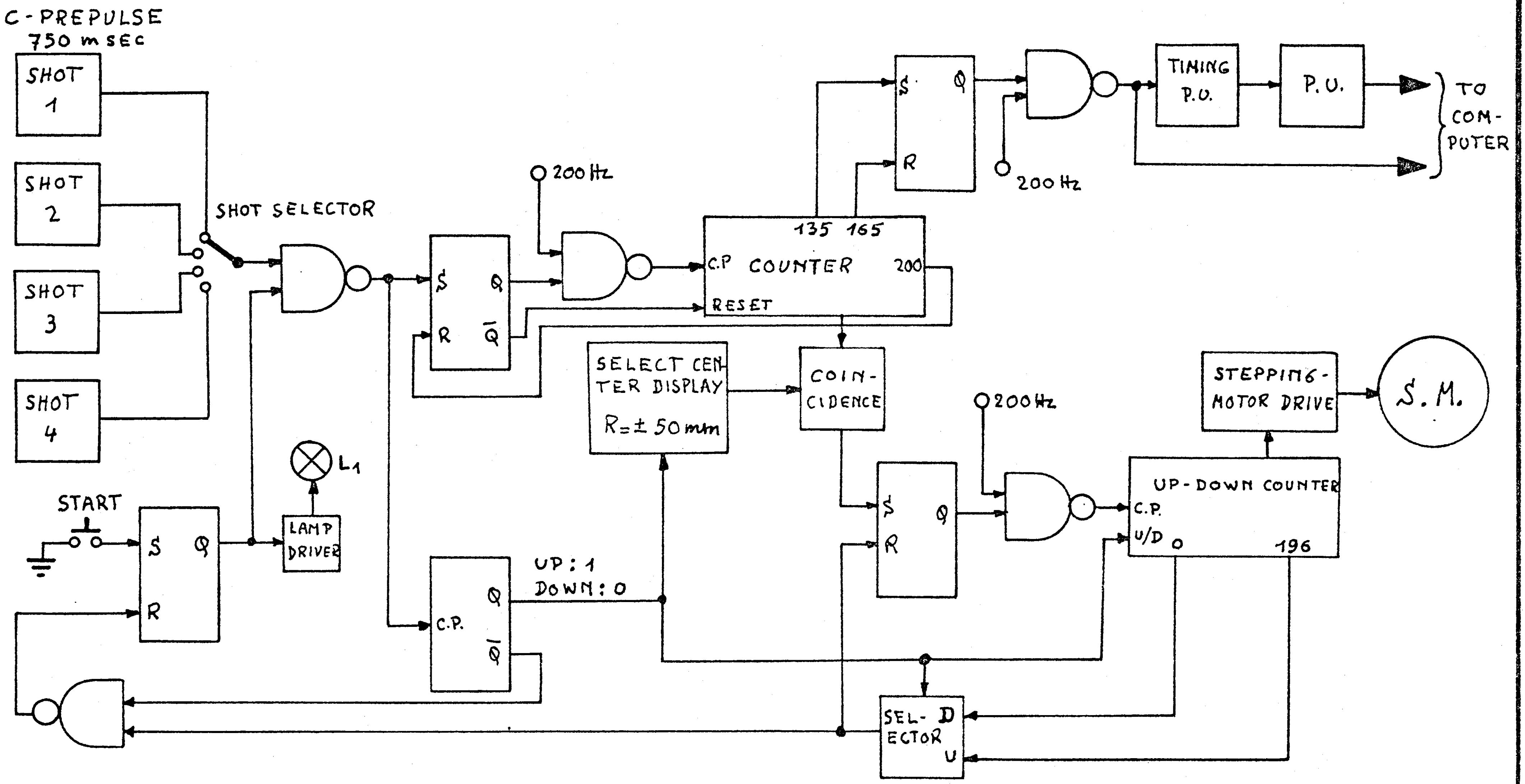

Fig. 8. Timing circuit for the target.