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AIR IONIZATION CHAMBER AS DETECTOR OF THE

BEAM LOSSES IN THE CPS RING

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Introduction

The principal objective of the improvement programme for the CPS is the increase in the mean intensity of the CPS by a factor of 10 - 15 [1]. The circulating beam proton losses will increase by the same or an even higher factor if no care is taken in avoiding them. **The circulating** beam losses are of two main kinds, excluding those occurring at injection and transition:

a) losses due to interactions of the high energy protons with the residual gas molecules inside the vacuum chamber of the CPS;

b) losses due to completely unknown processes occurring accidentally, mainly during operational perturbations of the proton beams' normal trajectory for internal target or ejection proton utilization.

The first kind are of a very low level under normal vacuum conditions ($\sim 10^{-6}$ mm Hg) [2]. They will also be of a low level with higher intensities and are directly proportional to the accelerating and flat-top period and the residual gas pressure inside the vacuum tube. These losses are equally distributed all around the ring.

The second kind are very important and up to now the real process and mechanism of these accidental losses are not known. However, experience has proved that they occur simultaneously with internal target or ejection operations but still nothing is known of where they take place or why. It is also known that there is a kind of random periodicity of these losses if one point at each machine

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1) P.H. Standley The CPS Improvement Programme MPS/Int.DL 65-12

2) B.D. Hyams and V. Agoritsas Background in ISR AR/Int.SG/65-29

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cycle is considered. The existing monitoring system of the relative efficiency of the internal targets is far from being complete for fulfilling this task. Some measurements of the induced activity done by the Health Physics Group using "Jordan" portative counters as well as some aluminium activation measurements merely confirmed that losses really take place [1].

It is therefore imperative to install a beam-loss detection system all around the ring, accompanied by a data display or registering system in the MCR, which will permit seeing in one machine cycle the time and space distributions of these losses around the ring and to compare them with other machine parameters observed simultaneously.

History of the Problem

J.H.B. Madsen, in a memo (MPS/CO, 14.4.1965), summarized the problem of beam loss measurements in the CPS ring, indicating possible detection techniques and the need for a simple data display system in the MCR. Since then, some meetings have been held and some work carried out [2] [3]. There is no doubt that many methods and different techniques can be used, but one has to choose from amongst them the most simple, reliable method, demanding a minimum of maintenance and low cost. These restrictions arise from the fact that the detection system will comprise a large number of units. In the following paragraphs a beam loss measuring system is proposed, using as detector an Air Ionization Chamber and a simple data display and printing system in the MCR.

Air Ionization Chamber

For many years parallel plate ionization chambers satisfactorily fulfilled the function of measuring radiation intensities. Ionization Chambers are simple in concept and construction, especially when the interplate medium is AIR, but because of ionic recombination they become unable to collect all the ions

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1) S. Charalambus Investigation des Pertes du Faisceau Interne du PS par Activation d'Aluminium DI/HP/51

2) N.J. Bradley Ways of Beam Loss Detection in the PS Machine MPS/Int.CO 65-13

3) G. Rosset Proposal for Measurements of Beam Losses in the PS Machine using Pulse Reflection Technique in a Coaxial Ion Chamber MPS/CO, 29.4.1966

produced in the chamber as the beam current density increases. The non-linearity of the air ionization chamber (from now on called AIC) starts at values of 10^{10} - 10^{11} ionizing particles per second per mm^2. We believe that these values can easily be avoided in the PS ring by choosing the right shape for the AIC and its definite position in the ring.

An ancient spark chamber frame was used as the base of an AIC. The dimensions are shown in Fig. 1. It was installed in the target 1 area along the #1 beam just in front of the lead collimator, about 4.5 meters from the target (see Fig. 2). We chose this position in order to be able to compare the AIC output with that of #1 under normal operation of the target No. 1. The block diagram in Fig. 3 shows the inter-connections of the AIC with the bias battery and measuring or display devices. The signal foils of the AIC are either connected directly, or through a very high isolation reed relay to a condenser. The built-up voltage on the condenser, due to the signal change, is then measured by an electrometer amplifier.[1)] The analogue output of the amplifier can then be directly displayed on an oscilloscope or be digitised and printed as it is indicated. The results obtained with this AIC are summarized in Figs. 4 and 5. The bias curve shows that there is a small difference in the first part of the curve between the positive and the negative bias and saturation (complete collection of ions is somewhere around 100 volts and this is the same for positive or negative bias). The shape of the curve remains the same even for a bias of ± 2000 volts. This means that the collected charge is due to the primary produced pairs. The linearity curve is excellent. The fluctuation of the AIC signal against that of #1 is less than 1% over 500 successive bursts with all machine parameters remaining constant. Here again, there is no difference between a positive or negative bias. The linearity measurement was carried out with ± 500 volts. Each time the target efficiency changed because of some malfunctioning, the linearity also disappeared.

The indication of the No. 1 target efficiency change was obtained by observing the ratio between I.P and #1 signal. In all cases, the AIC signal was relatively equal to or higher than the #1 signal. This means that the AIC was seeing more radiation than #1. This is normal because if protons are consumed elsewhere than the target head, the #1 monitor does not see the secondary particles produced but the AIC does.

1) V. Agoritsas A General Purpose Electrometer Amplifier (in preparation)

Numerical Results

Earlier measurements with monitor #1 showed that the counter coincidence output was the number of charged particles traversing the one cubic centimeter of the counter scintillator [1]. So a counting rate of 6000 counts/burst means that 6000 charged particles of a higher than 2 MeV energy traversed the scintillator. Believing that the distribution of the particles is relatively the same in the AIC position and applying the well-known square law, we found that for 6000 on one square centimeter in #1 place, the particles at AIC position will be 200.000/cm^2, and the surface of the AIC is 1000 cm^2. This implies that the AIC was traversed by at least 2.10^8 charged particles of higher than 2 MeV particles. The corresponding collected charge on the AIC condenser was then 3.10^{-7} coulombs, i.e., 2.10^{12} elementary charges, or pairs produced in the AIC interplate volume. This means that each charge particle produces 10^4 pairs traversing 5 cm air, i.e., 2500 pairs per cm^2. Therefore, the present AIC output signal is 10.000 times higher than the traversing number of charged particles. With such an amplification we can easily deal with very low particle fluxes around the machine by simply increasing the number of foils of the AIC. We shall not define just now either the shape or the dimensions of the AIC of the final installation. Such a choice still needs some investigation and discussion. Anyhow, the cost of such a chamber is very low and the biggest part goes to the workshop. The material cost itself is around 10 Sw.frs.

MCR Data Display System

Each AIC collecting foil lead will be connected through a change-over reed relay contact to a condenser of 100 - 500 nF. The normal condition of the collecting foil lead will be earth potential through the coaxial cable characteristic resistance. The collecting foils will be connected to the corresponding condenser at a predetermined moment of the machine period, as well as the duration of the contact. The minimum contact duration for the moment is 2 msec and the maximum infinite. The charge collected on the condenser can stay there for

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1) V. Agoritsas, D. Dekkers Proposed CPS Monitoring System MPS/Int.Al 62-12
First Report on Performance Tests

hours. The built-up voltage on each condenser can then be measured through a multi-switch made up of reed relays, the number of which must be equal to the number of AIC's. One end of each relay is permanently connected to an electrometer amplifier, the output of which is directly connected to a display oscilloscope triggered some milliseconds before the first reed relay is energized. The voltage reading time of each condenser cannot be less than 2 milliseconds. The minimum period between the end of one reading and the beginning of the next must also be 2 milliseconds. During this 2 msec dead time, a reed relay contact will discharge the corresponding condenser and will reset the electrometer amplifier, preparing it for the next reading.

The electrometer amplifier output can also be connected to an appropriate digitizer, the output of which can be printed. Such an operation takes a much longer time, but the logic of the system will be of a versatile type, which will permit the collection of a predetermined number of AIC's to be printed, the omission of some, and the grouping of some, etc. We are not yet able to give an estimation of the total cost of the system which will also be a function of the total channels. The on-line computer may simplify this problem. Fig. 6 shows diagramatically the above-proposed MCR display for the beam losses in the CPS ring. Fig. 7 shows the wave form of the different signals, as well as the time recurrence of a particular application, i.e. each channel needs at least 4 msec time. An alternative solution would be the use of an electrometer amplifier for each AIC, then the transfer from one AIC to another could be done by means of an electronic switch which is much more rapid and its cost is much lower, but this will not cover the extra cost of the electrometer amplifier of each channel which is more than 1000 Sw.frs.

Acknowledgements

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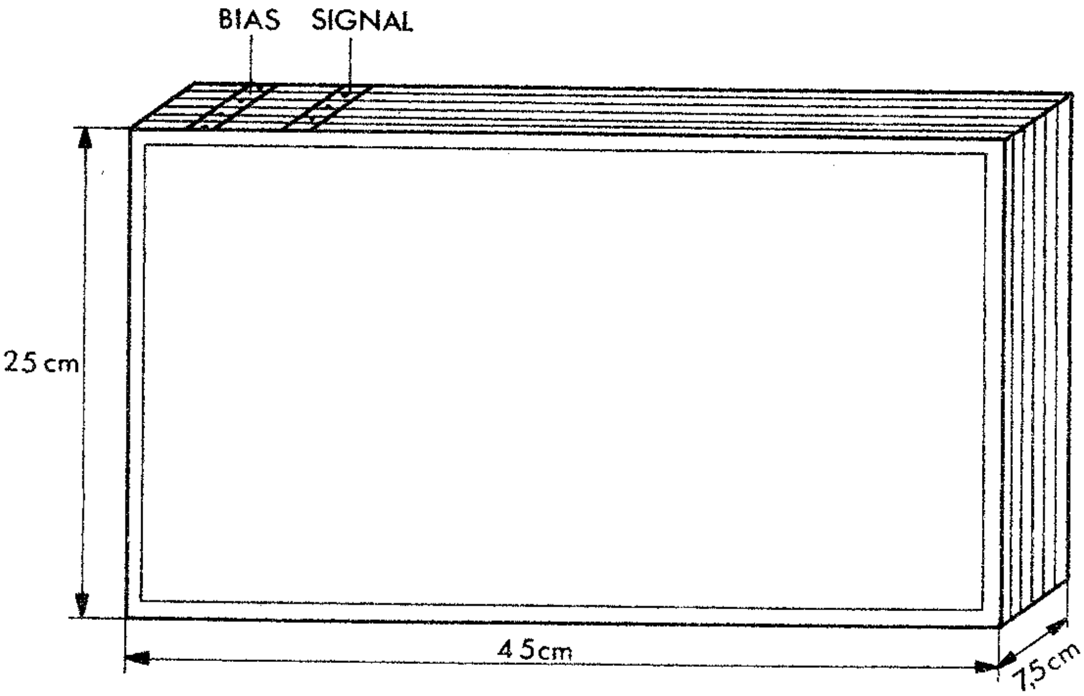

FRAME : LUCITE ~ 1cm WIDTH

FOILS : ALUMINIUM 25 MICRONS

SURFACE : 1125cm²

VOLUME : 8000 cm³

CAPACITANCE BETWEEN SIGNAL & BIAS CONNECTORS = 900pF

Fig.1 AIR IONIZATION CHAMBER

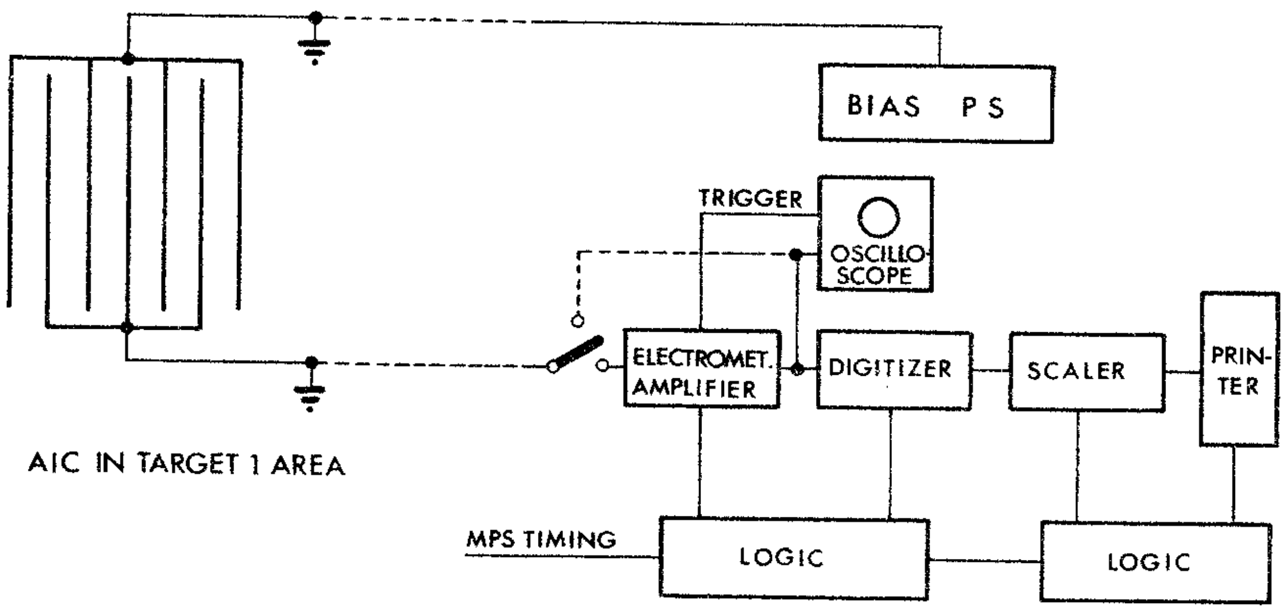

Fig. 3 AIC INTERCONNECTIONS

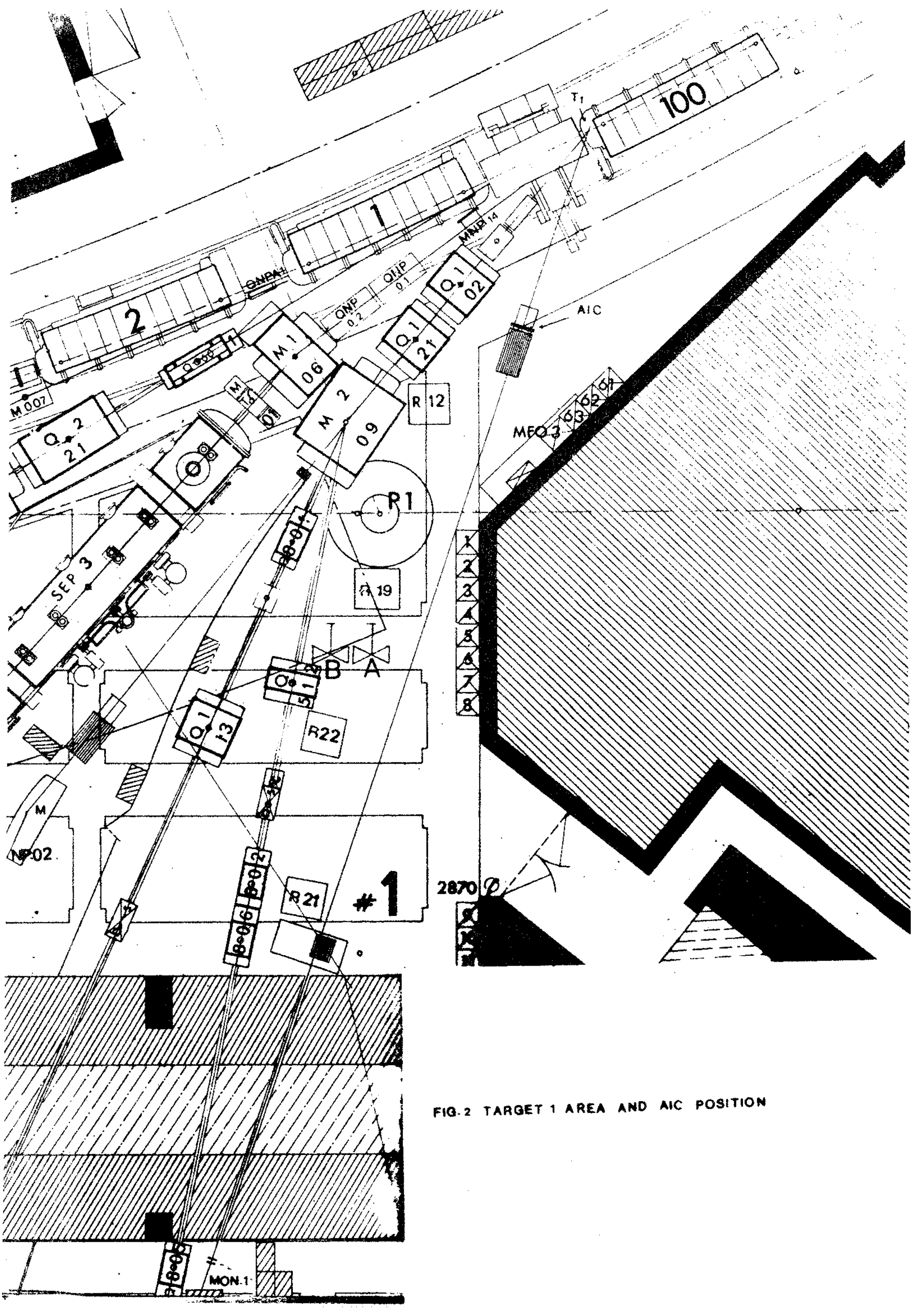

FIG. 2 TARGET 1 AREA AND AIC POSITION

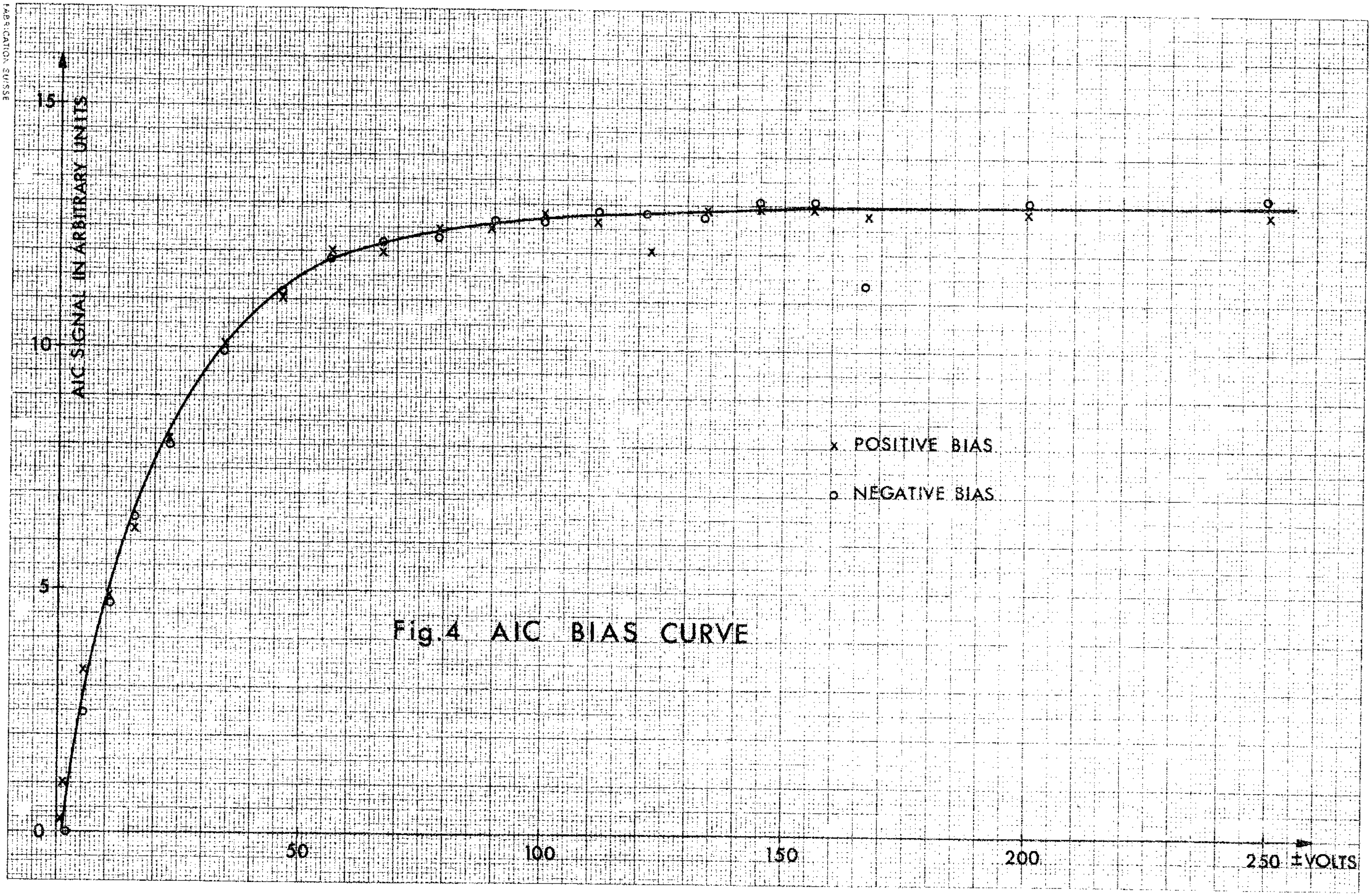

Fig.4 AIC BIAS CURVE

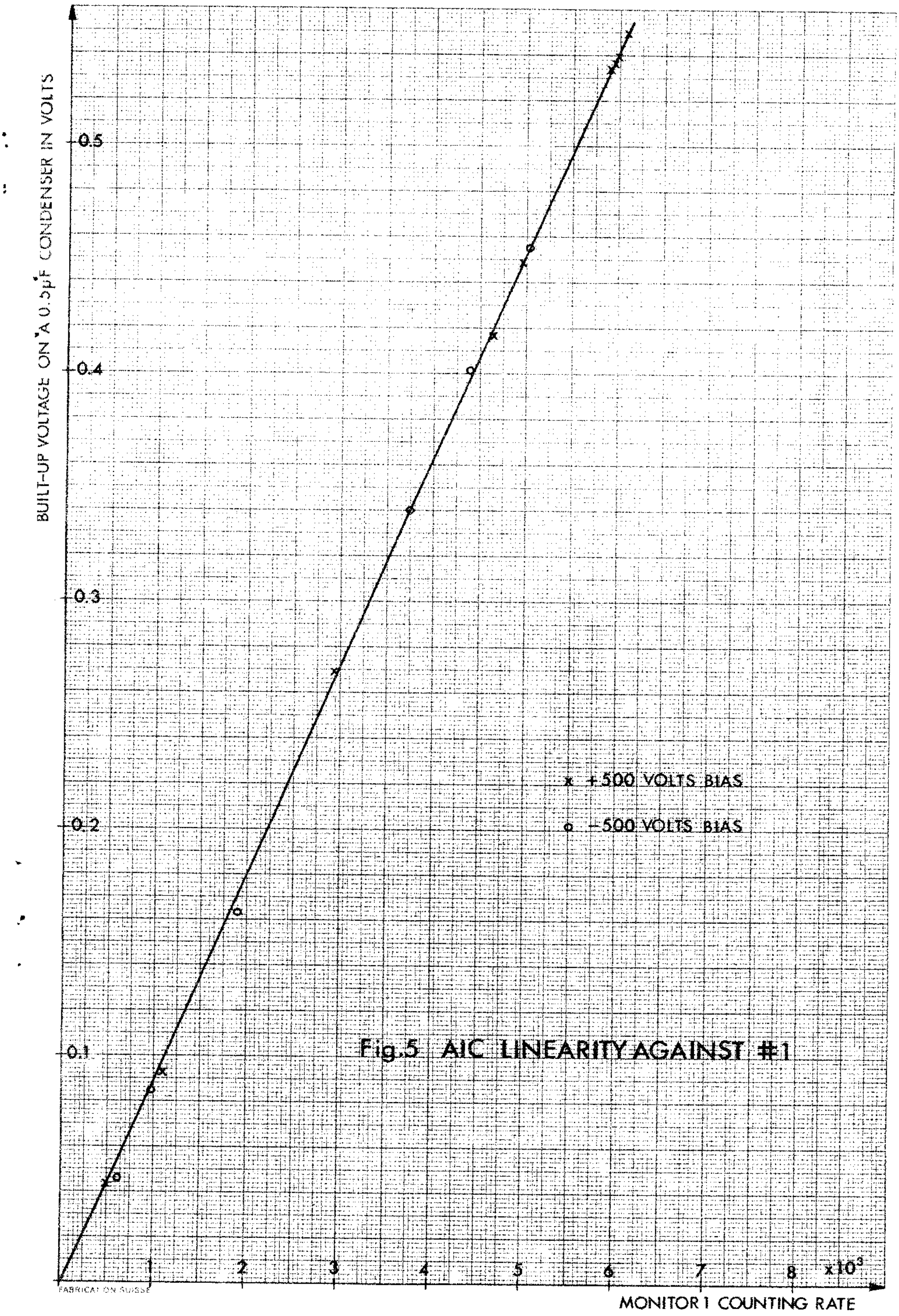

Fig.5 AIC LINEARITY AGAINST #1

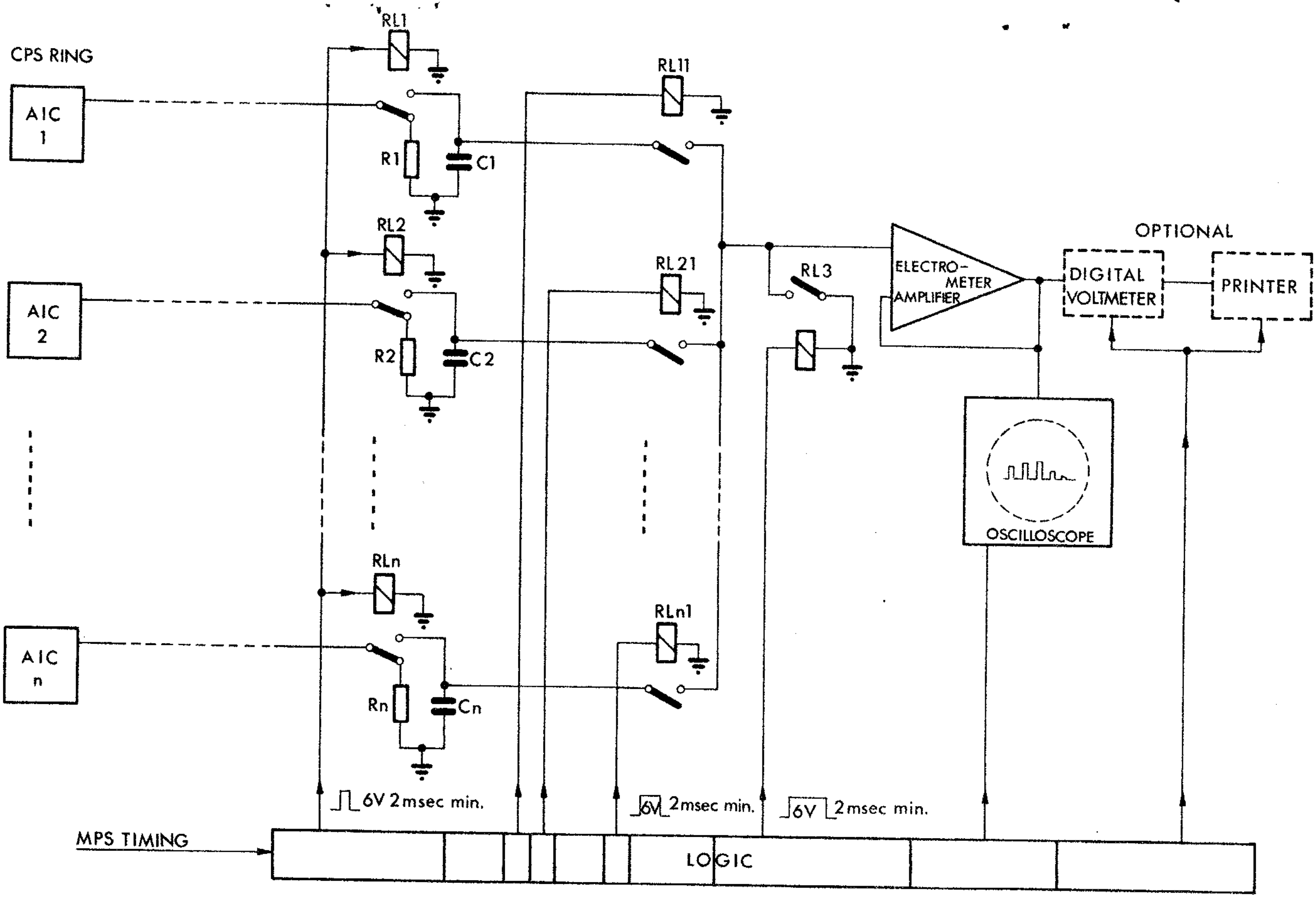

Fig.6 BLOCK DIAGRAM OF M.C.R. DISPLAY

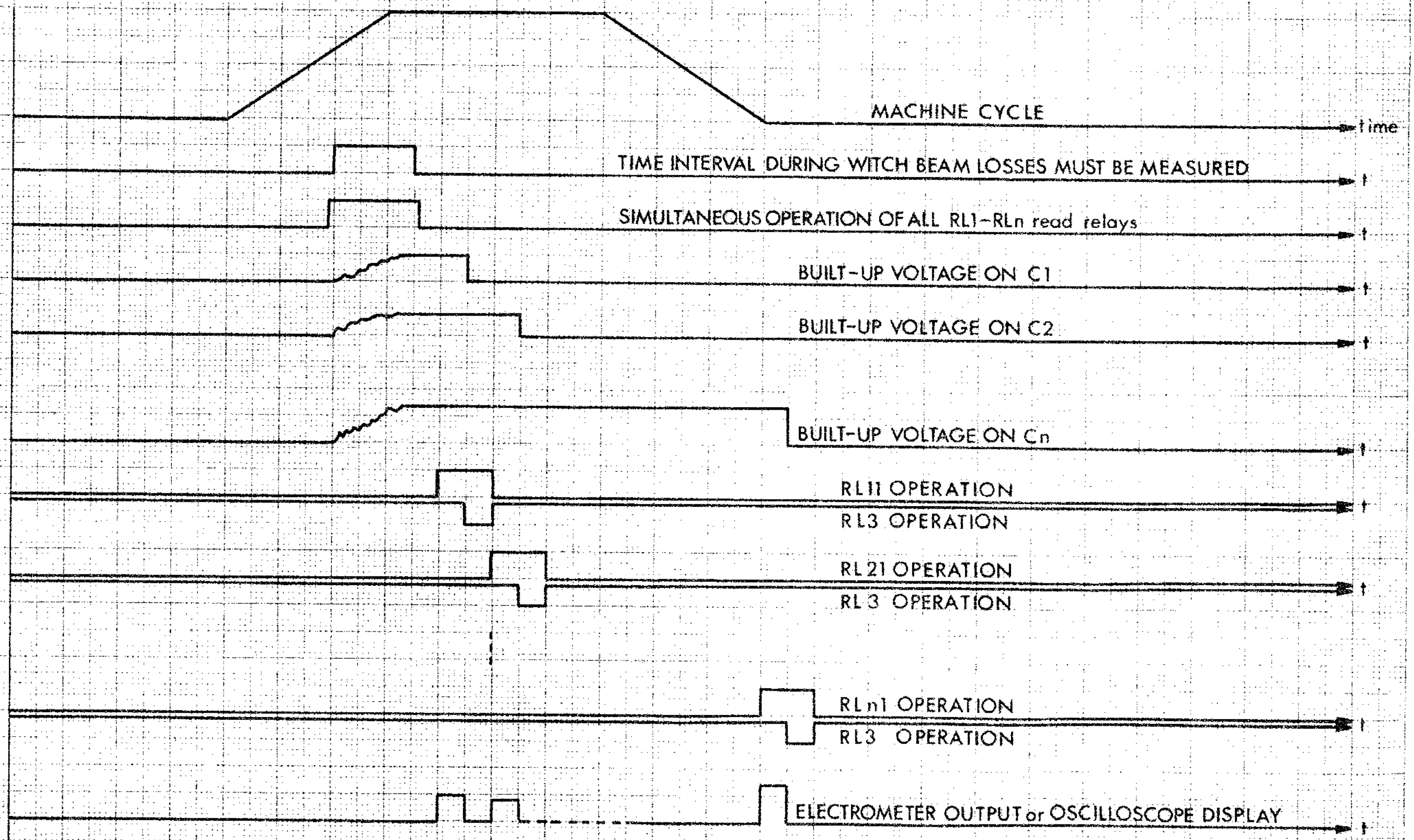

Fig. 7 WAVE FORMS AND TIME RECURENCE