A Counting Instrument with Linear Amplifier

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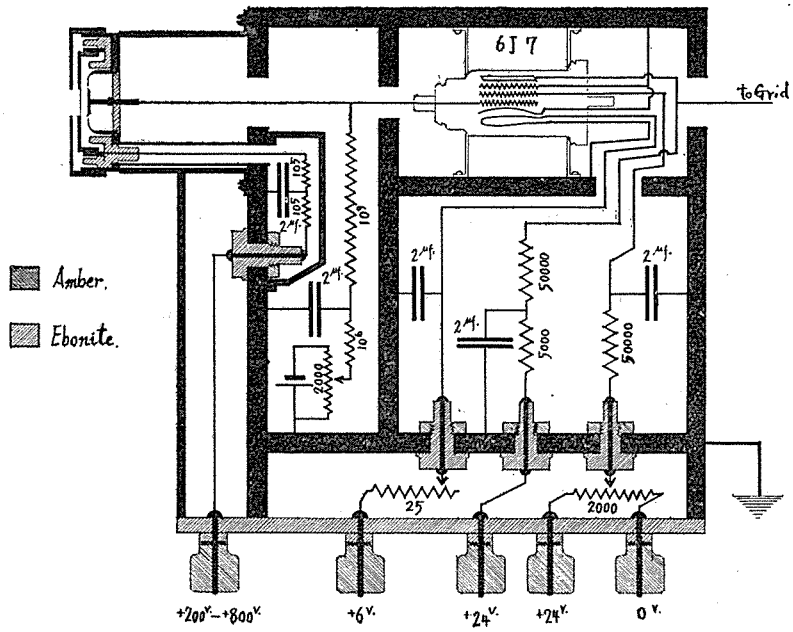
Recent development of nuclear physics has demanded the development of a new measuring instrument. A counter with linear amplifier was originally constructed by Greinacher[1] and then improved by Wynn-Williams and Wards[2]. Thereafter, several designs[3] were reported of amplifiers similar in principle to this one. In our laboratory too, the instrument was constructed with some improvements favourable to the study of nuclear transmutations[4]. Since, by careful construction and proper adjustment, the natural background of the count of this instrument is observed to be always less than one or two per hour in the case of the small ionization chamber described below, it is found to be most convenient for measuring the proton and alpha rays not only from strong sources but also from very weak ones, since even 3 of the particles per hour per cm^2 of the surface of an emitter may be ascertained.

Fig. 1



As the general description of an amplifier of this type is given by the writers cited above[1, 2, 3] it is only necessary here to describe the parts improved by the present workers.

a) Ionization Chamber

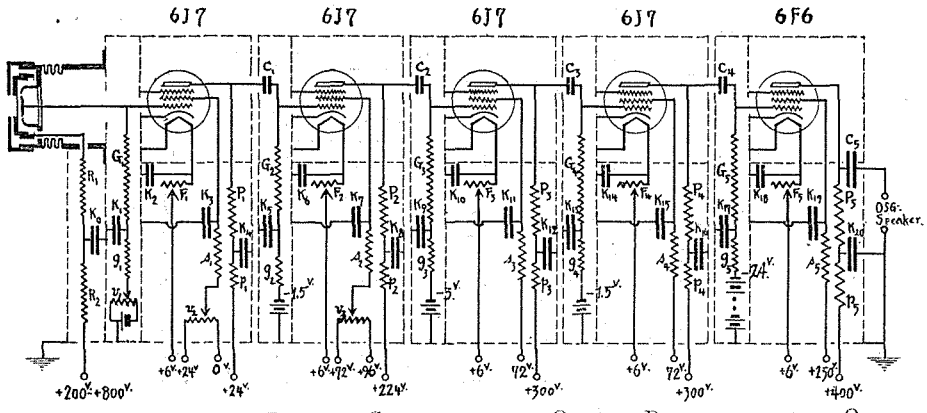
The counting chamber used (Fig. 1) is a parallel plate condenser having a collecting electrode 2 cm. in diameter. The inner electrode is surrounded at a distance of 1 mm. by a circular guard ring. The depth of the ionization chamber is made adjustable by screw between 10 mm. and 2 mm. (from the inner collecting electrode) and it has a circular opening 2 cm. in diameter covered by a thin sheet of aluminium or mica. The exterior of the outer electrode is shielded by an earthen cap with circular opening, which defines the effecting area of the source to be studied. This shielding is found to be indispensable for accurate measurement.

b) Linear Amplifier

The linear amplifier constructed by us is a form of resistance-capacity coupling. Having been used in several experiments[5] for long years, the function of this amplifier was successively improved so that it is used quite satisfactorily in the high voltage and crowded research laboratory. The circuit diagram is shown in Fig. 1 and 2 and the values of various components are indicated on the accompanying key.

i) *The first stage of the amplifier* As the most critical point of the

Fig. 2



$C_{1,2,\cdots,5}$	0.005 μF,	G_2	250,000Ω,	$P_{3,4}$	250,000Ω,
$K_{0,1,\cdots,20}$	2μF,	$G_{3,4,5}$	500,000Ω,	P_5	7,000Ω,
$R_{1,2}$	100,000Ω,	g_1	1,000,000Ω,	$P_{1,2,\cdots,4}$	5,000Ω,
$r_{1,2,3}$	2,000Ω,	$g_{2,3,4}$	20,000Ω,	P_5	2,000Ω,
$F_{1,2,\cdots,5}$	6Ω,	g_5	50,000Ω,	$s_{1,2,\cdots,4}$	50,000Ω,
G_1	10^9Ω,	$P_{1,2}$	50,000Ω,	s_4	2,000Ω.

amplifier comes in the first stage, the present workers, as have also all the others, have carefully laboured for this point. The valve of RCA-6J7 or UZ-77 (Tokyo Electric Company) was found to work satisfactorily (Fig. 1). This has, to a certain extent, desirable characteristics, i. e., low input capacitance, high amplification factor and non-microphonic construction. Because of its high noise level a valve of this type was considered by some workers unsuitable for the first valve, but this difficulty was overcome satisfactorily by proper control in the way described below.

After several tests it was found that the signal-to-noise ratio was approximately independent of the plate voltage over a wide operating range, but was closely dependent on the plate current as affected by control of screen grid voltage. The noise level could be greatly reduced by operating the valve at lower cathode temperature and with lower screen grid and plate voltage; for instance, a good condition was obtained by using a heating current of about 0.08 ampers, a plate potential of 24~48 volts and a screen potential moderately controlled between 12 and 24 volts.

In order to keep the amplifier always free from temporal impotence caused by some large electric disturbances and to gain high resolution of counting enormous numbers of particles in a short time without great sacrifice of sensibility, it is found desirable to use a grid leak resistance, at the first valve, of the order of 10^9 ohms with the grid voltage of about -0.8 volts which is the value of a floating grid. No remarkable increase of noise level was observed in this case as compared to the case of floating grid.

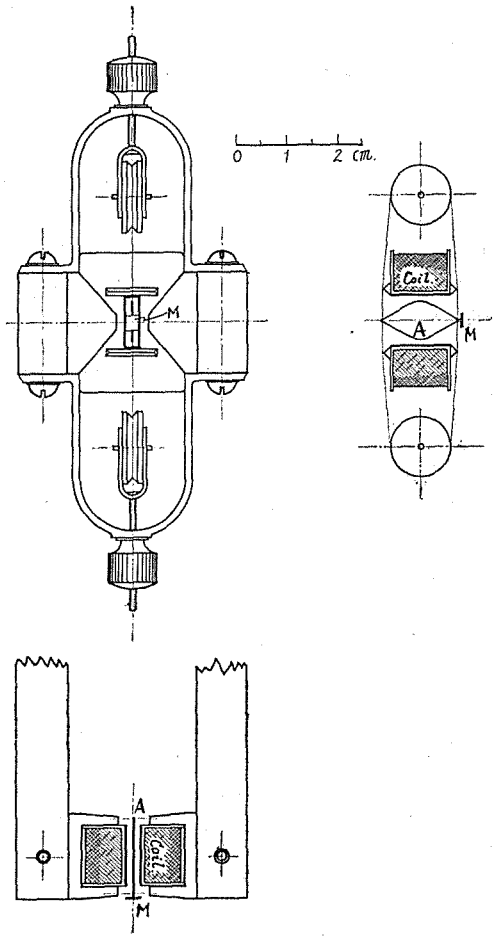
ii) *Shield case* The shield box of the amplifier was at first made from brass plate 3 mm. thick. But the brass plate of this thickness was found to resonate with sound waves from a neighbouring working machine and especially from a loud speaker connected parallel to the recording system itself; and so boxes of iron plate 1 cm. thick were substituted. The mere change of material was found very effective for obtaining good stability in the function of the amplifing system.

Each stage of the amplifier is mounted on a separate iron case which consists of three compartments; one for the valve, one for the filter circuit and one for the coupling circuit. To keep the valve from microphonic effect each valve has been suspended by soft springs with rubber sheet, and the connections were made entirely from flexible (dead beat) wires. In order to absorb mechanical vibration through the

table these iron boxes have been mounted on piles of wooden plates separated by pillars of sponge gum.

iii) *Control of amplification* As a slight change of the screen grid potential of the first valve has remarkable influence on the output of the amplifier, the control of amplification has been effected in this way without disturbing the lineation. This may be also possible at the second stage. It is desirable to control both complementarily, otherwise unwanted disturbances are experienced in the lineation. With other methods, published previously by several workers, this operation also may be a convenient method.

Fig. 3



c) Recording Apparatus

A simple oscillograph reconstructed from a balanced-armature-loud-speaker has been used. (This is preferable for observing the "kicks" since it records parallel to hearing.) A natural frequency of about 1000/sec may be obtained without difficulty. The construction was made following, in some respects, after Wynn-Williams[2]. (Fig. 3)

The soft iron armature A is a shallow rhomb in shape, the diagonals of which are 15 mm. and 8 mm. respectively. The vertices of the longer diagonal are suspended at the center of the speaker coil by two tungsten wires 80 μ in diameter forming sides of a loop which is stretched by means of a screw-and-pulley device. The distance between the two bridges of ebonite is 1.2 cm. For current coil, a speaker coil of 2000 ohms electrostatic resistance is satisfactory.

A thin galvanometer mirror M about 3 mm. square is attached to the armature. This whole part is immersed in liquid paraffin which acts as a damper. The optical system is mounted as usual.

Camera—A rotating paper (or film) camera was specially constructed so that a strip of highly sensitive bromide paper or photographic film stretched around a wheel is driven smoothly at various speeds by means of a phonomotor-and-pulley system. (Fig. 4)

The sensitivity of the oscillograph as usually operated was 1 mm. deflection per 2 volts at a distance of 60 cm. from the vibrator mirror.

d) The Characteristics of the Counting System

The lineation of the amplifying system and oscillograph as a whole was tested by inducing a known voltage of any frequency on the first valve grid and was found to be linear up to 1.5 cm. deflection at a distance of 60 cm. from the vibrator mirror. By using polonium source the Bragg's ionization relation was tested and found to be satisfactorily fulfilled.

The practical examples are reproduced in plate I.

In conclusion the authors wish to express their cordial thanks to Prof. Dr. B. Arakatsu for his kind guidance and valuable suggestions throughout this work, and at the same time their thanks are due to Hattori Hokokwai and Nippon Gakujutsu Sinkokwai for financial support in this work.

References

1. H. Greinacher Z. S. f. Phys., **36**, 364 (1926).
2. C. E. Wynn-Williams and Wards, Proc. Roy. Soc. A **131**, 391 (1931).
3. J. R. Dunning, Rev. of Sci. Inst., **5**, 387 (1934).
   S. Kikuchi and H. Aoki, Sc. Pap. I. P. C. R., **26**, 36 (1935).
   R. Sagane, do, **27**, 93 (1935).
4. B. Arakatsu, K. Kimura and Y. Uemura, Mem. of Fac. of Sci. and Agricult. Taihoku Imp. Univ. **8**, 75 (1936).
5. B. Arakatsu, K. Kimura and Y. Uemura, Nature **140**, 77 (1937).
   K. Kimura, Abstract of Research of Hattori Hokokwai **4**, 155 (1937).
   K. Kimura, Mem. of College of Sci. Kyoto Imp. Univ. **22**, 237 (1939).

Explanations of Plate I.

a——α-particles from the natural surface of Hokutolite.
The thickness of absorber: 13 mm. in air equivalent.
The depth of the ionization chamber: 7 mm.

b——α-particles of Po deposited on a copper plate.
The thickness of absorber: 20 mm. in air equivalent.

The depth of the ionization chamber: 2 mm.

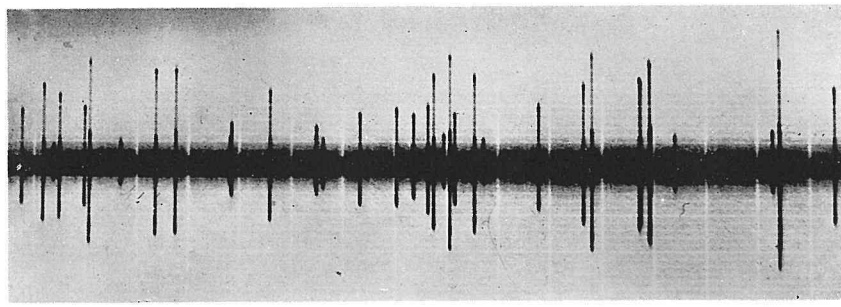
c——α-particles of Po deposited on a copper plate.
The thickness of absorber: 30 mm in air equivalent.
The depth of the ionization chamber: 2 mm.

d——Homogeneous α-particles (12.7 cm) by the reaction: $Li^6+D^2\rightarrow 2\,He^4$. (thick Li_2O-target).
The thickness of absorber: 8.3 cm. in air equivalent.
The depth of the ionization chamber: 2 mm.

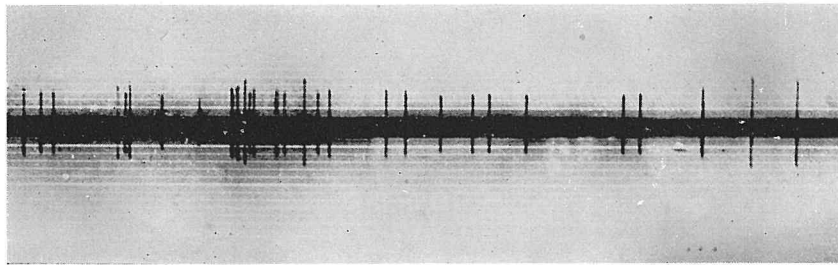
e——Homogeneous α-particles (4.5 cm.) by the reaction: $B^{11}+H^1\rightarrow Be^8+He^4$ (thick borax target).
The thickness of absorber: 4 cm. in air equivalent.
The depth of the ionization chamber: 4mm.

Plate I

a



b



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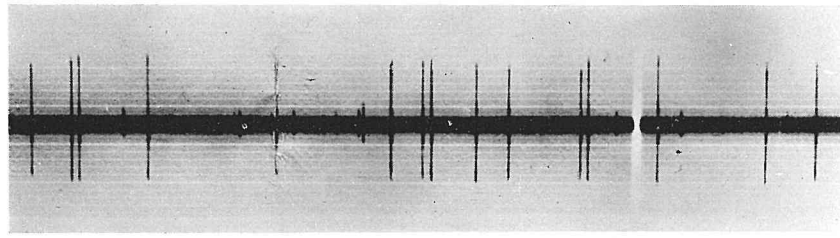
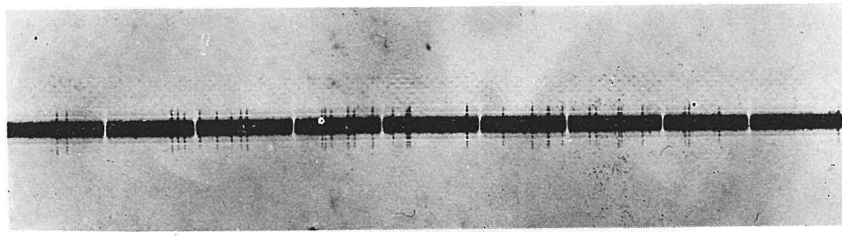


d



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