CAPACITY EFFECTS ON DELAY LINE PICK-UPS FOR KICK MEASUREMENTS

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1) The kick of the Janus K.M. prototype has been measured with a delay line pick-up. Due to the presence of electrical stray fields the risetime and the amplitude of the kick can be measured incorrectly by these pick-ups. In order to evaluate the influence of these electrical stray fields a simulated KM was built with no magnetic coupling between the magnet itself and the loop.

The delay line pick-up had the following characteristics :

length	l	=	100 cm
width	w	=	0,6 cm
characteristic impedance	z_o	=	75 Ω
propagation time	τ_d	=	5 ns.

Fig. No 1 shows the set up of the system.

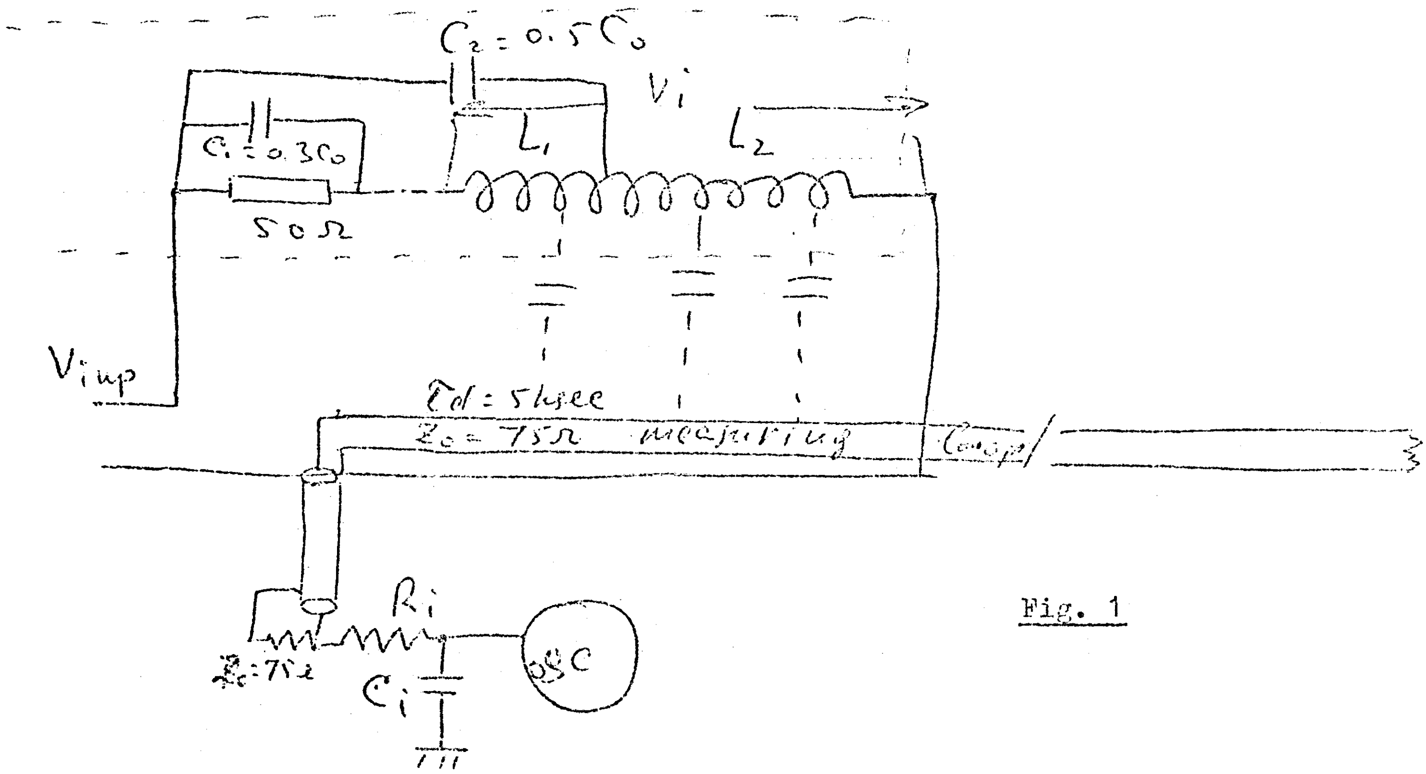


Fig. 1

Since the length of KM is 30 cm and its propagation time is 1,5 ns it is possible to replace the distributed stray capacities between the magnet and the loop by an equivalent lumped capacity C_s placed at the beginning of the KM.

The equivalent electrical circuit is shown in Fig. 2.

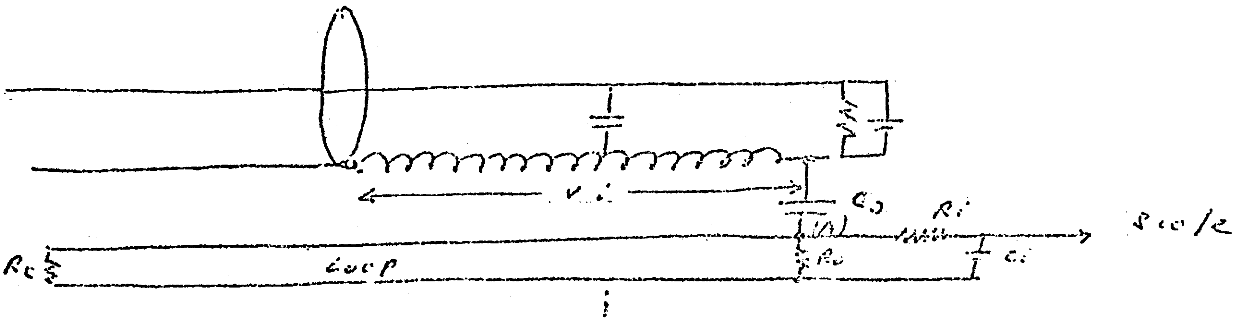


Fig. 2

If :

v_i (t)	=	voltage across the magnet
v_{ro} (t)	=	voltage across the resistance R_o at one end of the loop.
C_s	=	equivalent stray capacity between KM and pick-up placed at point A
Z_o	=	R_o characteristic impedance of the pick-up
τ_s	=	$R_o\ C_s$
τ_i	=	$R_i\ c_i$ = Time constant of the integrator

Because C_s from a rough estimation <10 pF; τ_s << risetime of V_i and we can write :

$$v_{Ro}(t) = \frac{\tau_s}{2}\left[\left(\frac{d\,V_i(t)}{dt}H(t) + \frac{R_e - R_o}{R_e + R_o}\,\frac{dV}{dt}(t - 2\tau_d)\;H(t-2\tau_d\right.\right]$$

where $H(t-2\tau_d)$ is the Heaviside function

Fig. 4,7,9 show V_{Ro} for the different values of R_e

(Fig. 4 : $R_e = R_o$, Fig. 7 : $R_e = 0$, Fig. 9 : $R_e = \infty$).

The voltage across C_i will be

$$v_{ci}(t) = \frac{1}{\tau_i}\int_0^t v_{Re}(t)\,dt$$

$$= \frac{\tau_s}{2\tau_i}\left[v_i(t) + \frac{R_e - R_o}{R_e + R_o}\, v_i(t - 2\tau_d)\, H(t - 2\tau_d) \right]$$

Figs. 5, 8, 10 show v_{ci} for the different values of R_e

(Fig. 5 : $R_e = R_o$, Fig. 8 : $R_e = 0$, Fig. 10 : $R_e = \infty$)

In the case $R_e = R_o$ we have

$$v_{ci}(t) = v_i(t)\,\frac{\tau_s}{2\tau_i}$$

From where we can easily get

$$C_s = \frac{V_{cix}\, 2\tau_i}{V_{ix} R_o}$$

In our case we had $V_{cix} = 45$ mV, $V_{ix} = 150$ V

$\tau_i = 260$ ns $R_o = 75\,\Omega$

$$C_s = \frac{2 \times 45\ 10^{-3} \times 260\ 10^{-9}}{150 \times 75} = 2\ \text{pF}$$

The same procedure was used for measuring the value of C_s for different positions of the delay line in the KM aperture.

Fig. 13 shows the variation of C_s in the (y) vertical direction at three different radial position of the loop at 60 mm, 25 mm and 5 mm from the cold plate.

2) Distortion of the kick.

In the real case we have to add to the kick the pulse induced by the electrical stray field into the loop.

The pulse at the output of the integrator will be then :

$$v_{tot}(t) = v_K(t) + v_{ci}(t)$$

Let's call $M(t)$ the ratio between $v_{tot}(t)$ and $v_K(t)$

$$M = \frac{v_{tot}(t)}{v_K(t)} = \frac{v_K(t) \quad v_{ci}(t)}{v_K(t)} = 1 + \frac{v_{ci}(t)}{v_K(t)}$$

where $$v_K = \frac{1}{\tau_i} \int_0^t v_1 \, dt$$

where $v_1(t)$ is the voltage across R_o induced by the magnetic field into the pick-up.

If we don't take in account the delay of the pick-up for the magnetic field, we can write

$$v_1 = \frac{F_e}{F_A} \frac{d\phi}{dt} \frac{R_o}{R_c + R_o} = \frac{F_e}{F_A} \times V_i(t) \times \frac{R_o}{R_c + R_o}$$

where

F_e = width of the pick-up delay line,

F_A = width of the aperture.

In our case :

F_e = 6 mm

F_A = 140 mm.

We can estimate the maxima of $v_{ci}(t)$ and $V_K(t)$ for the three cases of $R_e = R_o$, $R_e = \infty$, and $R_c = 0$.

1) $R_e = 0$

$$V_{cix} = \frac{\tau_s}{2\tau_i} \times V_i(t = 2\tau_d)$$

$$V_{Kx} = \frac{F_e}{F_A} \int_0^{t=2\tau_d} V_i \, dt = \frac{F_e}{F_A} \frac{\tau_s}{\tau_i}$$

$$M_x = 1 + \frac{\frac{\tau_s}{2\tau_i} V_i(t=2\tau_d)}{\frac{F_e}{F_A} \frac{1}{\tau_i} \int_0^{t=2\tau_d} V_i \, dt} = 1 + \frac{\tau_s F_A}{2 F_e} \frac{V_i(t=2\tau_d)}{\tau_s}$$

2) $R_e = R_o$

$$V_{cix} = \frac{\tau_s}{2\tau_i} V_i$$

$$V_{Kx} = \frac{F_e}{F_A} \frac{1}{2\tau_i} \int_0^{t=200ns} V_i(t)\,dt = \frac{F_e}{F_A} \frac{\Phi_x}{2\tau_i}$$

$$M_x = 1 + \frac{\frac{\tau_s}{2\tau_i} V_{ix}}{\frac{F_e}{F_A}\frac{1}{2\tau_i}\Phi_x} = \frac{\tau_s V_{ix}}{\frac{F_e}{F_A}\Phi_x}$$

3) $R_e = \infty$

$$V_{cix} = \frac{\tau_s}{\tau_i} V_{ix}$$

$$V_{Kx} = \frac{F_e}{F_A} \frac{1}{2\tau_i} \int_0^{t=2\tau_D} V_i(t)\,dt = \frac{F_e}{F_A 2\tau_i} \Phi_{(t=2\tau_D)}$$

Case 3 is relevant only because it allows us to see practically only the stray field.

Case 1,2 instead are the cases used in our measurements.

In these cases it is important to evaluate the values of M_x.

In our case :

$L = 0{,}56\ \mu H$

$I_x = 8.000\ A$

$\Phi_x = L\, I_x = 0{,}56\ 10^{-6} \times 8 \cdot 10^3 \cong 4{,}5\ 10^{-3}\ W$

$V_{ix} = 60\ kV$

$\tau_s = 2\ 10^{-12} \times 75 = 150 \cdot 10^{-12}$ sec.

1) $R_e = R_o$

$$M_x = 1 + \frac{V_{ix}}{\frac{F_e}{F_A}\Phi_x} = 1 + 0{,}042$$

2) $R_e = 0$ $\qquad \tau_d = 2{,}5$ ns $\qquad V_{i\,(t=2\tau_D)} \cong 12$ kV

$$M_x = 1 + \frac{\tau_s \; V_i(t = 2\tau_d)}{\frac{F_e}{F_A} \; \Sigma_x} = 1 + 0{,}01$$

From these values we can conclude that a) in the case of one short circuited end the electrostatic effect has never a relevant event and that in matched loop its maximum is only of 5°/o.

It may be useful to evaluate $M(t)$ during the risetime of the pulse for the case $R_e = R_o$

We have then

$$M(t) = 1 + \frac{\tau_s \; v_i(t)}{\frac{F_e}{F_A} \int_0^t v_i(t)\, dt} = 1 + \frac{\tau_s \, F_A}{F_e} \; \frac{v_i(t)}{\int_0^t v_i(t)\, dt}$$

Fig. 3 shows the shape of $v_i(t)$. We can assume with good approximation that v_i is of the form

$$v_i(t) = V_{i0} \left[\frac{t}{\tau_{RS}} \; H(t) - \left(\frac{1}{\tau_{RS}} + \frac{1}{\tau_K} \right) (t - \tau_{RS}) \; H(t - \tau_{RS}) - \frac{t - \tau_K}{\tau_K} \cdot H(t - \tau_K) \right]$$

For $t \gg \tau_{RS}$

$$M(t) = 1 + \frac{\tau_s \, F_A}{F_e} \cdot \frac{1 - \frac{t - \tau_{RS}}{\tau_K} - \frac{t - \tau_K}{\tau_K} \, H(t - \tau_K)}{\frac{\tau_{RS}}{2} + (t - \tau_{RS}) \left(1 - \frac{t - \tau_{RS}}{2 \tau_K} \right)}$$

Fig. 14 shows the behaviour of $M(t)$ as function of the time. From there we can easily see that after 160 ns the influence of stray field is negligible.

High voltage measurements

In order to check the low voltage measurements the delay line pick-up has been put into the prototype at 80 kV. Once it was short-circuited and once open circuited at one end. In the first case given the very short delay of the pick up = 2,5 ns, we measured the magnetic field, in the second case we induced into it only stray field.

Graphs A,B show pictures of the two cases. The peak of the stray field is = 30 mV, when the top of the magnetic field v_K is = 400 mV, then the ratio between the maxima is 3000/400 = 8°/o.

The values are sligthly higher than the low voltage measurements probably for the higher value of C_s, but still very small.

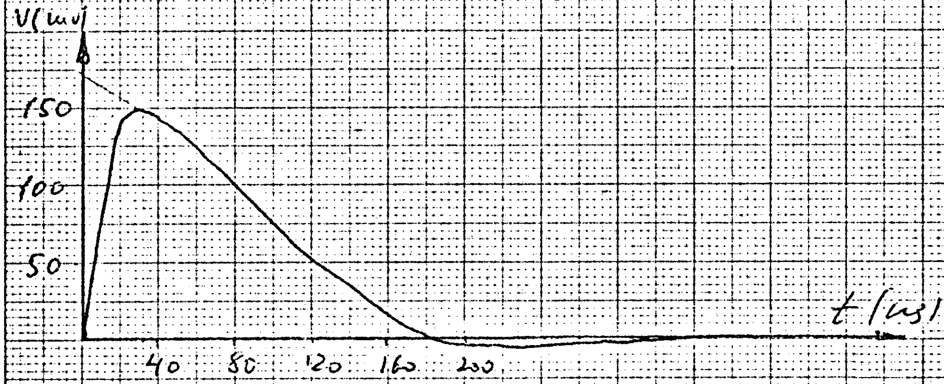


Fig 3

V_i

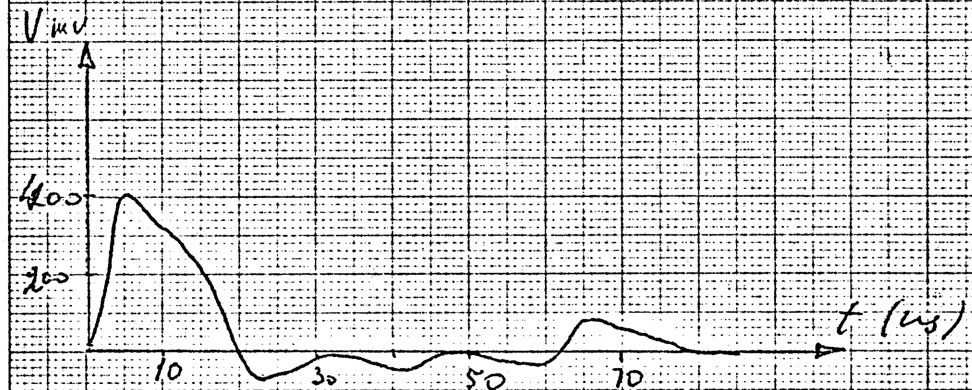


Fig 4

V_{RO} $R_c = R_o$

Fig 5

V_c $R_c = R_0$

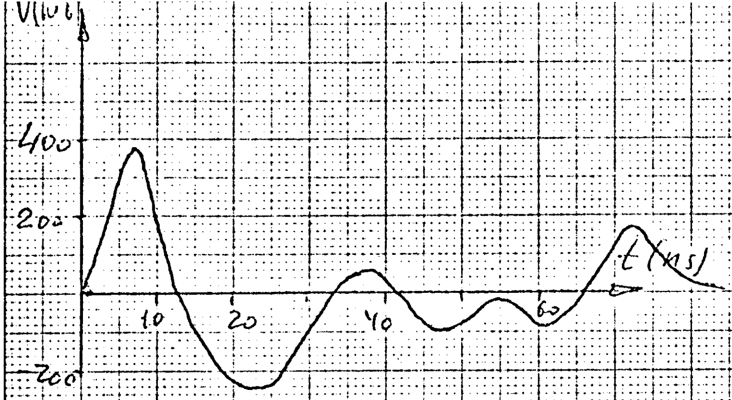


Fig 7

V_{R0} $R_c = 0$

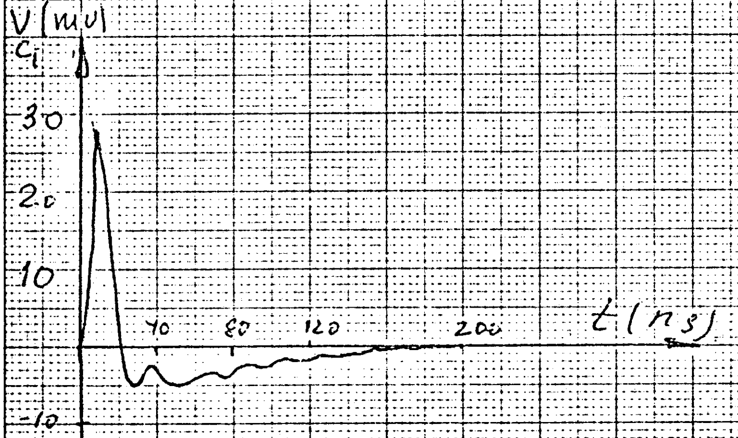


Fig 8

V_{Ci} $R_c = 0$

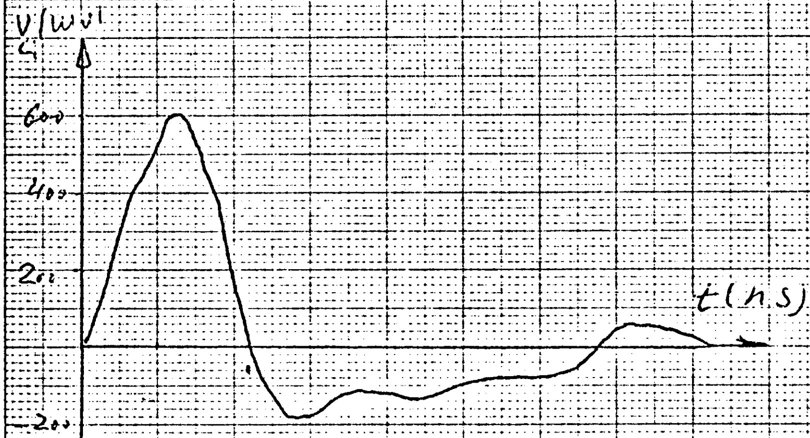


Fig 9

V_{R0} $R_c = \infty$

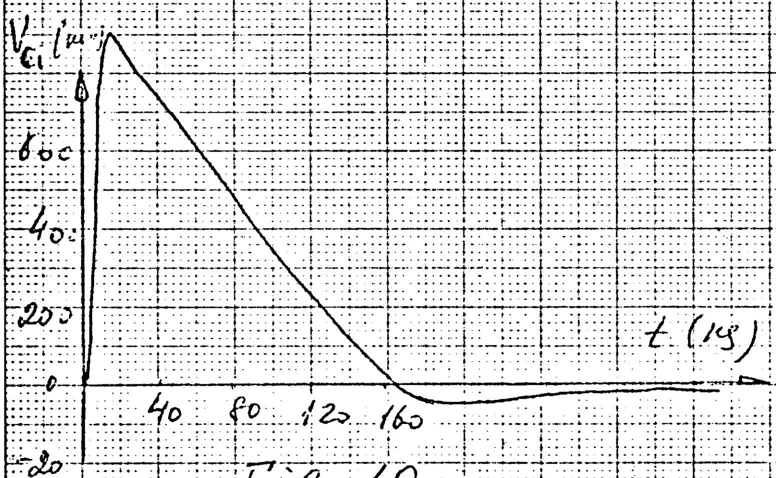


Fig 10

V_{ci} $R_c = \infty$

FABRICATION SUISSE

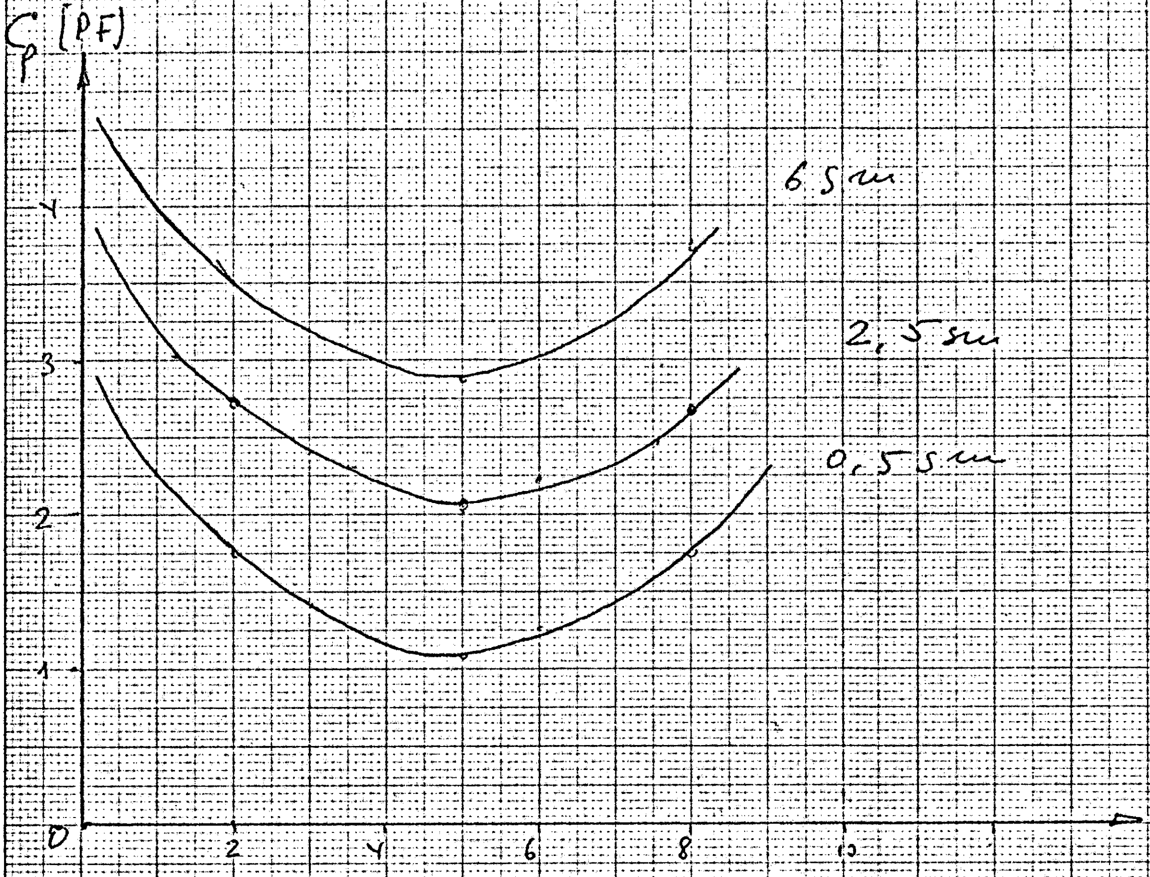
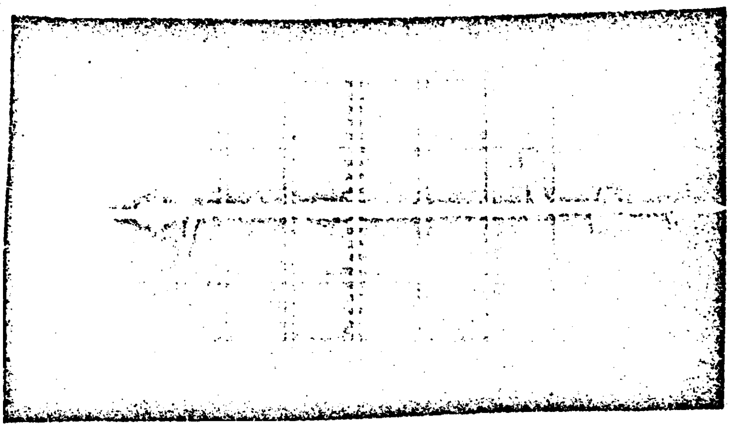


Fig 13 Cs as function of vertical position

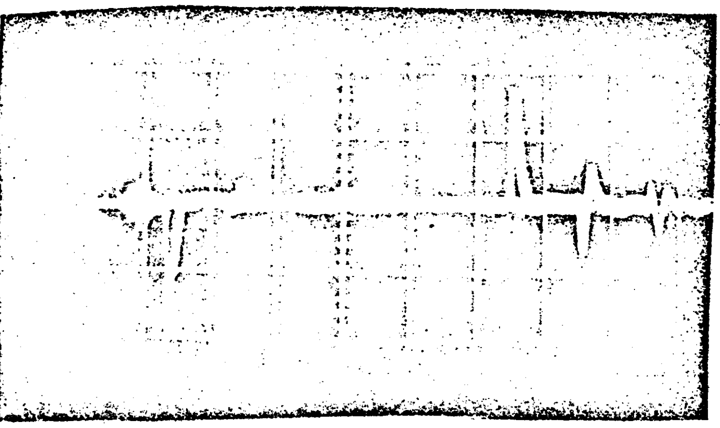
Fig 14 M-1 as function of the time

group A



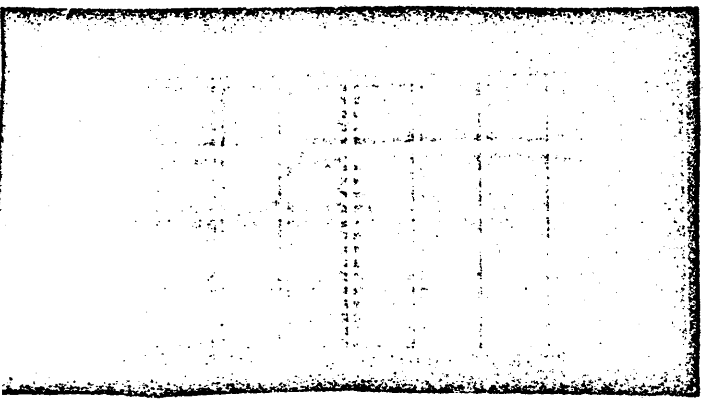
X = 1 μsec/D

Y = 10 mV/D



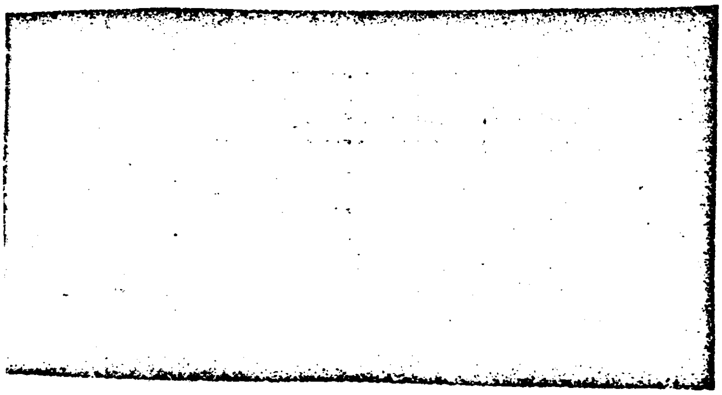
X = 1 μsec/D

Y = 10 mV/D



X = 200 ns/D

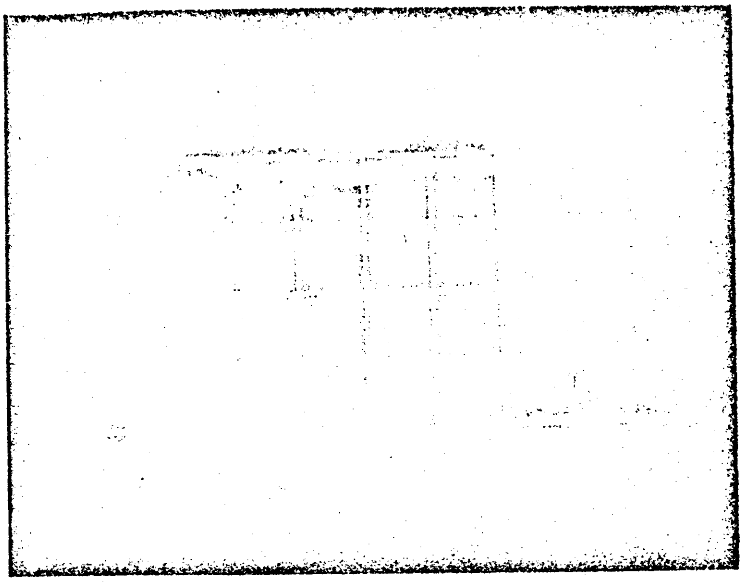
Y = 10 mV/D



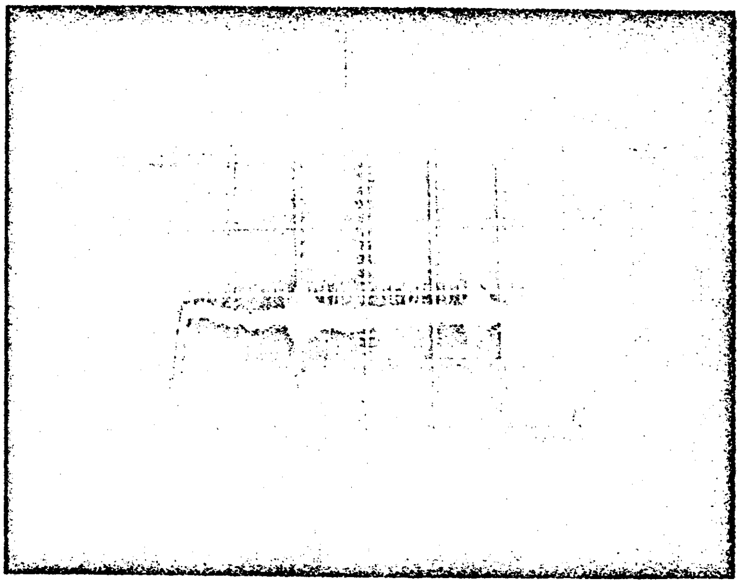
X = 100 ns

Y = 10 mV

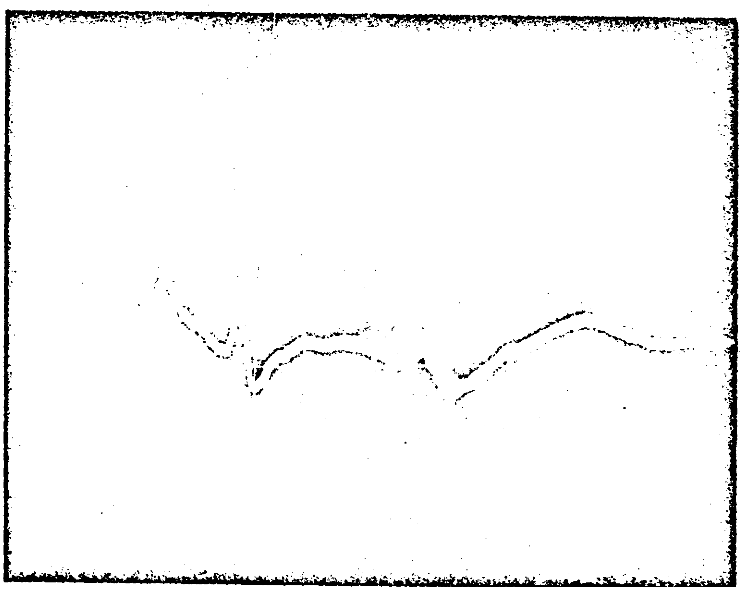
group B



1 µs/□
100 mV/□



1 µs/□
200 mV/□



500 ns/□
20 mV/□
max = 403 mV
min = 407 mV
Flat top