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PS/BT/Note 87-11
17.11.1987

AC EJECTION KICKER FOR AA COMPLEX

K.D. Metzmacher
L. Sermeus

SUMMARY

After cooling in the Antiproton Collector ring (AC), the antiproton beam is rebunched prior to transfer to the Antiproton Accumulator ring (AA). It is then kicked by four delay line type kicker modules working in a short-circuited mode.

This note describes this kicker system and gives the useful parameters to use it correctly.

1. INTRODUCTION

This note describes the kicker system built for the ejection of $\bar{p}$ from the AC ring in the AA complex.

The main part deals with the magnets but a summary of the pulse generator characteristics described in ref. [1] will also be given.

2. BEAM REQUIREMENTS

After cooling in the AC, the antiproton beam is rebunched with a bunch length of 360 ns, an emittance of 25π mm.mrad and a relative energy spread of $\frac{\Delta p}{p}$ = .25%.

AC rotation time being 629,14 ns, this allows a gap of 270 ns for the kick rise time (5 - 95)%, assuming that 5% of the full kick will touch the last particle before ejection and 95% the first particle of the bunch to be ejected.

The kick flat-top must be at least 360 ns long with a uniformity of ±1%.

The total deflection angle requested is θ = 9,84 mrad ($\int Bdl$ = 0,1173 T.m).

The magnet aperture has to be designed to allow the circulation of the 240π mm.mrad injected beam, while the "good" field region (±1%) needed is small according to the dimensions of the 25 π mm.mrad ejected beam.

Image straight sections 35 and 50 have been chosen to place the kicker tanks (Fig. 1).

Tank K50 should also be able to provide 66% of the total deflection in normal operation for machine acceptance reasons.

3. KICKER SYSTEM

A. Magnet design

According to the beam dimensions (2), (3), the kick strength required, the kick rise time and the space allowed, it appeared that it was not possible to perform the kick strength with terminated 15 Ω full aperture magnets. Furthermore, the 15 Ω magnet impedance could not be changed because of the necessity to reuse the old AA injection generators (with a minimum of changes), solution which was the most economical and realistic.

The use of moving reduced aperture modules as in AA ejection kicker has not been retained because of the problems involved by such a system placed in a vacuum tank and used at a high rep rate.

The decision of using short-circuited magnets has then been taken as for AC injection kicker (5). This solution provides twice the current and hence twice the kick strength for the same PFN voltage (but it roughly doubles the kick rise time).

Due to the large beam spread in the sections and the rise time allowed, it has been necessary to split the kicker into four modules placed in two image tanks, each tank containing two different modules.

The magnet construction follows closely that used for AC injection kicker (transmission line type magnets). Whilst the tanks are not bake-able, the magnets can be baked to 300 ^{0}C if necessary. The modules are closed C-apertures constructed with 24 cells and have a maximum of similar or identical components. A photo of one of these magnets is given in Fig. 2.

In order to define a good field region with a uniformity of ± 1%, the C-core and conductor shapes have been designed with the help of POISSON and MAGNET programs. A plot of flux lines given by POISSON for K35-1 is shown in Fig. 3.

Table 1 summarizes the main characteristics of the magnet.

Figures 4 and 5 show the disposition of the magnets in the tanks and the beam envelope.

B. Pulse generator

Each magnet is powered by a 15 Ω cable PFN pulse generator and is short-circuited outside the tank by special LEMO connectors (Fig. 6). This last feature permits to reverse the kick direction by reversing the current direction in the magnet. In counterpart, roughly 5 ns are lost in additionnal travelling time for the wave to reach this short-circuit, be reflected and fill the magnet a second time.

Table 2 gives the PFN voltages required to perform the kick in different operation modes. In case of failure of one module, the three remaining ones provide still sufficient strength. Maximum operating voltage is 80 kV. The particle fly-time delay between sections 35 and 50 has been implemented in the hardware and can't be changed (7).

C. Performances

a) Low voltage measurements

As for AA and AC injection magnets, these measurements have been done with an HP pulse generator providing the pulse of Fig. 7 in a 15 Ω resistor load. The magnet was short-circuited at one end. The propagation of the leading edge of this pulse through the 24 cells of magnet K50-2 is shown in Fig. 8. The integrated field along beam axis ($\int Bdl$) and $\frac{d\Phi}{dt}$ are shown in Figs. 9 and 10 (K35-2). The time to reach the 100% kick value is four times the travel time of the magnet due to unavoidable mismatches and negative coupling between cells. This can be very much improved by connecting a capacitor at the magnet entry for compensation (Fig. 11).

The field uniformity measured with a strip line probe is shown in Figs. 12 a) and b).

b) *High voltage measurements*

After installation in their respective tank [6] and pumping down, magnets have been pulsed at 80 kV some 10^5 shots before final installation in the AC ring. Their performances at that PFN voltage with a corresponding current of 5200 A have been measured.

A typical ($\int Bdl$) photo measured with a strip line probe is shown in Fig. 13 (K35-2). In order to compensate the system's unavoidable mismatches, capacitors of 470 pF have been connected to the magnet ends. The $\int Bdl$ thus obtained is shown in Fig. 14, where we can see an improvement of the flat top. The (5-95)% rise time measured from this photo is 250 ns.

Currents at magnet input and output measured with PEARSON TYPE 110A transformers are shown in Figs. 15 and 16. SPICE calculations give very similar results (Figs. 18,19 and 20) with the equivalent circuit of Fig. 17. The maximum flat top length available is 450 ns.

CONCLUSION

The AC ejection kicker system which is in full operation in the AA complex from end of July 1987 has been described in this note. The system has successfully been used to eject protons and antiprotons from the AC ring and to inject protons into the AC ring.

REFERENCES

1. A pulse generator for short-circuited delay line magnet excitation D. Fiander et al CERN/PS/BT 85-35.

2. Acol injected and ejected beam sizes deduced from a perturbation method based on "orbit" data, M. Martini, PS/ACOL/Note 28.

3. R. Sherwood, Private communication.

4. ACOL Ejection kicker magnet proposals, K.D Metzmacher, L. Sermeus, PS/AA/ACOL Note 85-25.

5. AC injection kicker for AA complex, K.D Metzmacher, L. Sermeus, PS/BT/Note 87-9.

6. Inj. and Ej. systems at straight sections 55/56 and 35/50 of the AC. G. Betty, PS/ML/Tech. Note 85-10.

7. The monitoring system for the ejection and injection kicker magnets of the $\bar{p}$ accumulator and $\bar{p}$ collector, C. Maddison, PS/BT/Note 86-6.

List of drawings :

PS-C-0733-22-0 : Ensemble K35-2/K50-1
PS-C-0734-22-0 : Ensemble K35-1/K50-2
PS-C-0794-22-1 : Straight section 35
PS-C-0796-22-1 : Straight section 50

Distribution :

AA Scientific Staff
BT Scientific Staff

TABLE 1.

Data	Units	K35-1/K50-2	K35-1/K50-1
w (w_{eff})	mm	250 (204)	292 (215)
h	mm	100	90
n	cells	24	24
l (l_{eff})	mm	576 (600)	576 (600)
V_{PFN}	kV	80	80
Z_0	Ω	15	15
I	A	5200	5200
$\int Bdl$	T.m	.0392	.0435
θ	mRad	3,29	3,65
L	μH	1,54	1,8
C	pF	6836	8005
T_M	ns	103	120
B_{air}	T	0,0653	0.0726
$B_{fer\ mid\ cell}$	T	0,2023	0,2014
$B_{fer\ end\ cell}$	T	0,3035	0,3021
w_{fer}	mm	85	100
V_{fer}	cm^3	29261	36828
M_{fer}	Kg	155	195
A_M	mm x mm	598 x 876	598 x 876
l_M	mm	620	620
l_{tank}	mm	1388	

Remanent kick strength at 80 kV : 3,15 10^{-4} T.m per tank

TABLE 2

Tank	θ (mrad)	No. of Modules	V_{PFN} (kV)
K35 K50	3,28 6,56	2 2	37,5 75
K35 K50	4,92 4,92	2 2	56,5 56,5
K35 K50	3,28 6,56	1 2	80 75
K35 K50	6,54 3,3	2 1	75 80

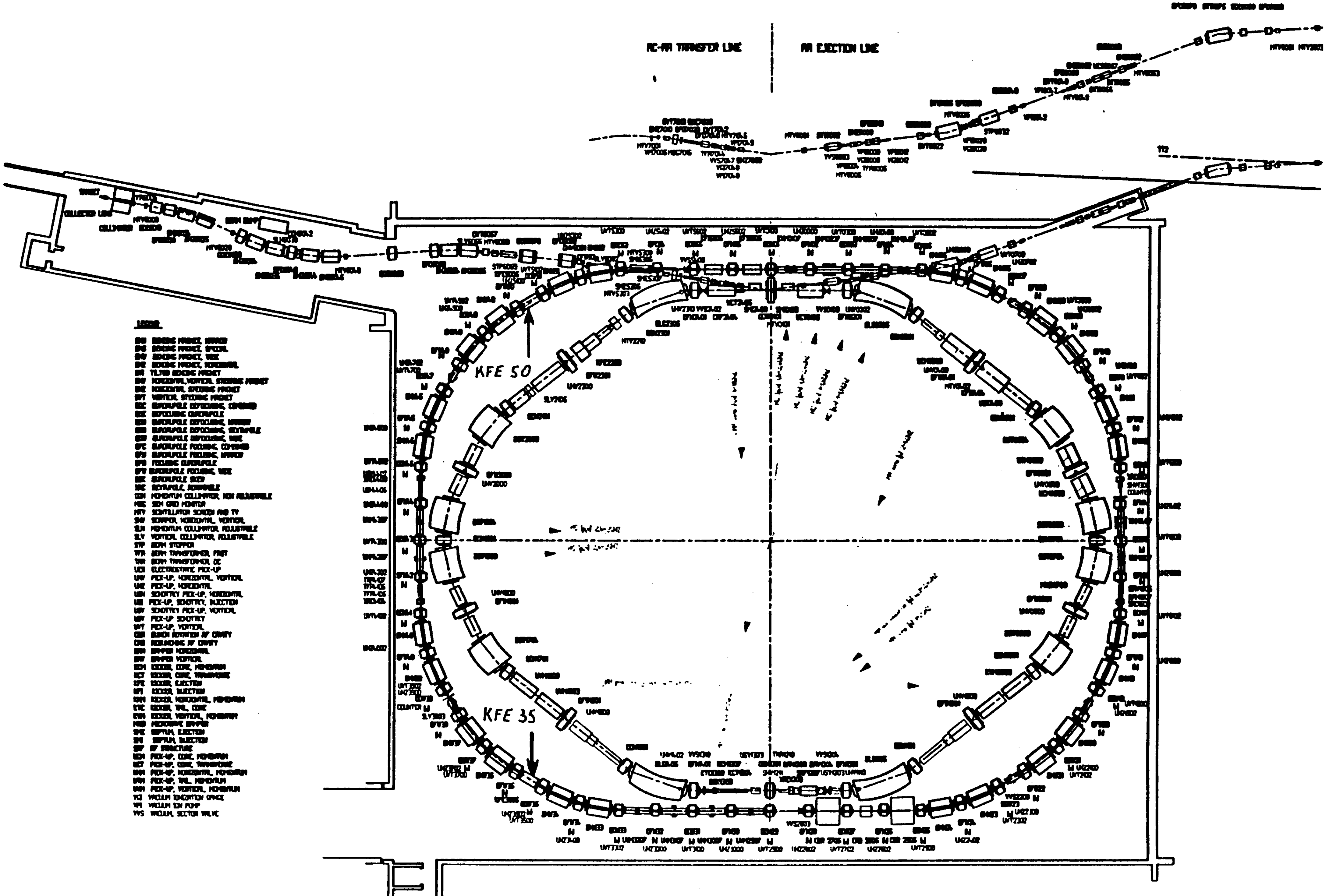


FIG. 1. ANTIPROTON ACCUMULATOR LAYOUT

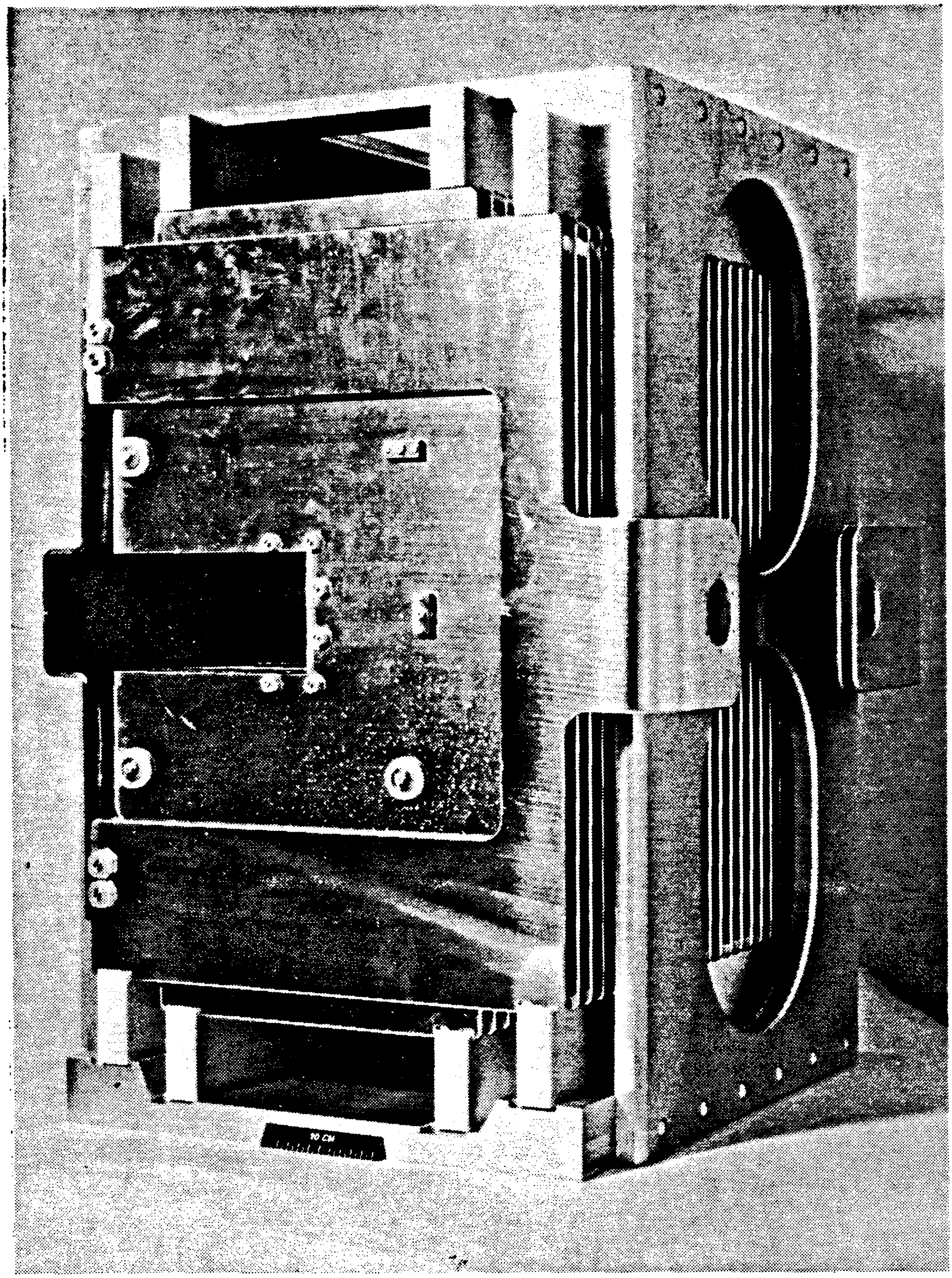
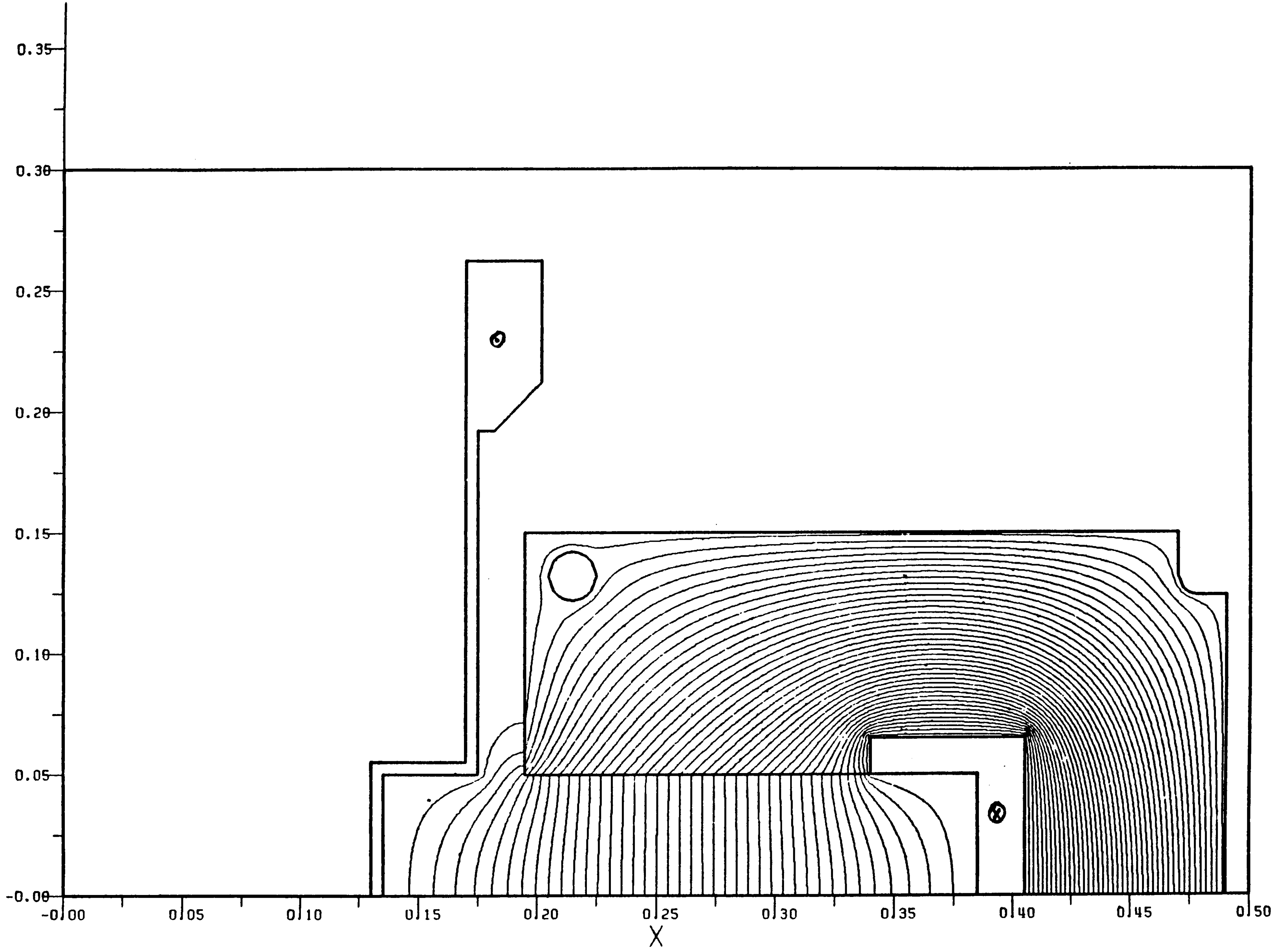
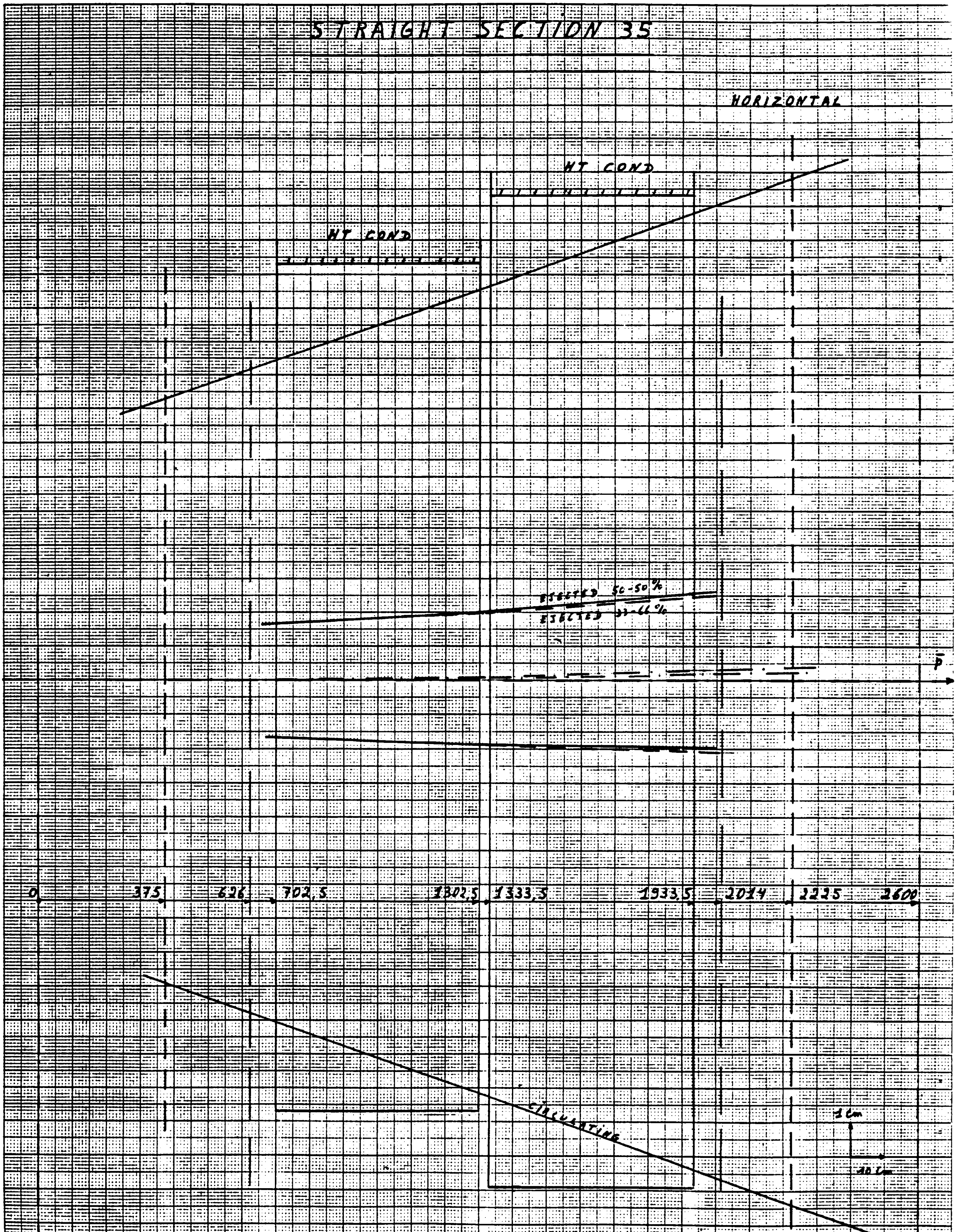


FIG. 2 Module K50-2.

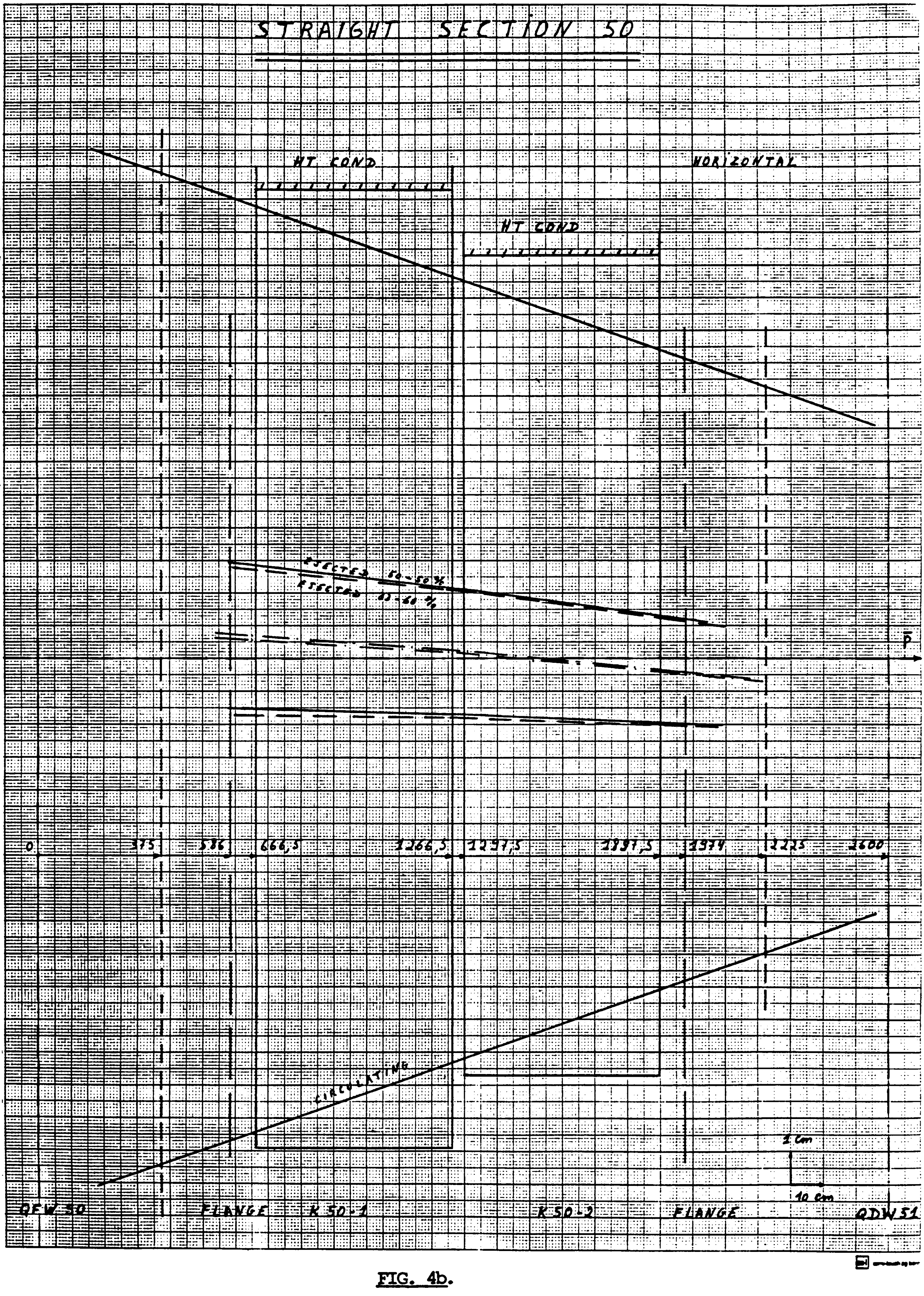


<u>FIG. 3</u> POISSON plot of flux lines K35-1.



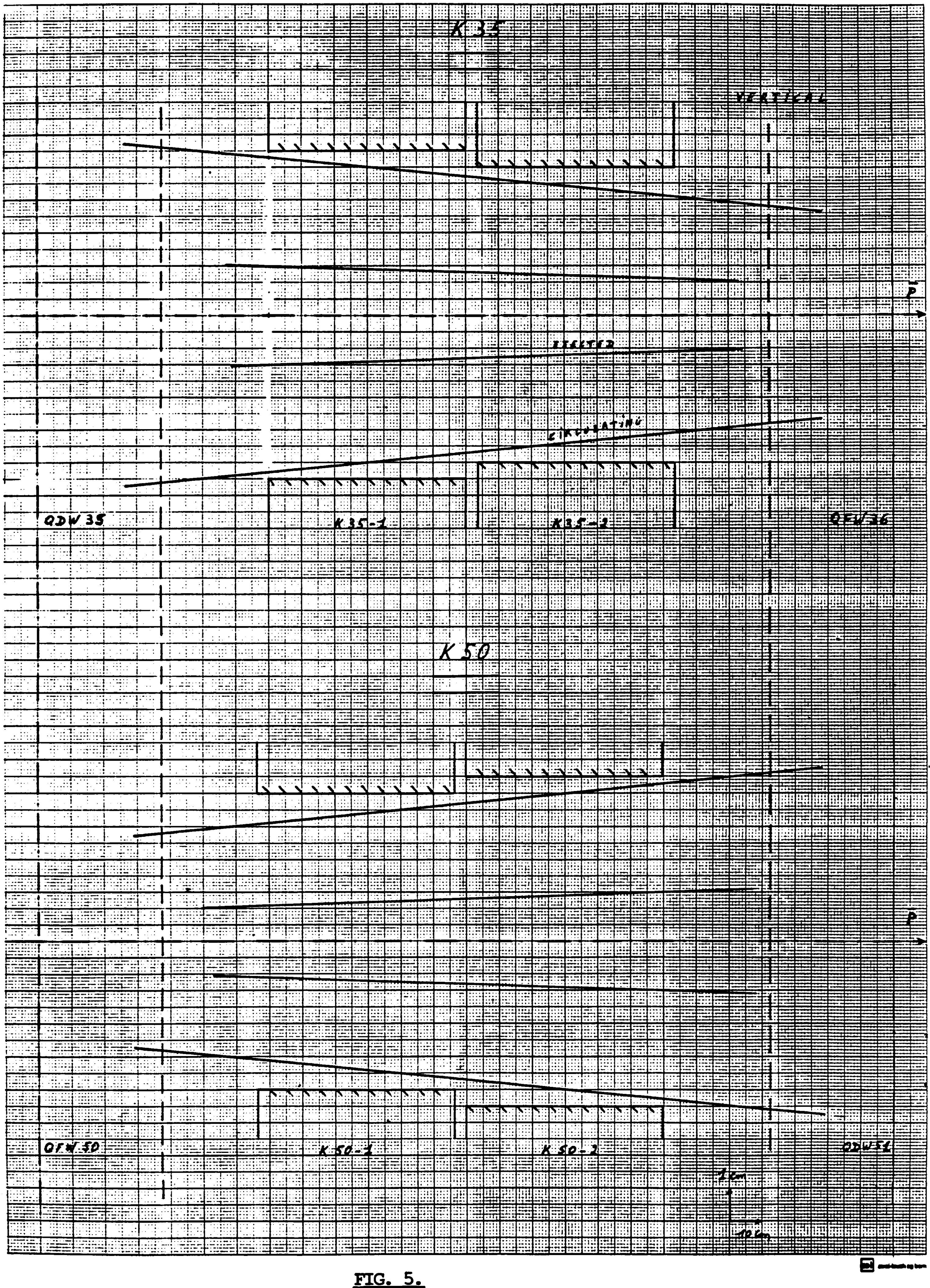
STRAIGHT SECTION 35
HORIZONTAL
HT COND
HT COND
EJECTED 50-50%
EJECTED
P
0
375
626
702,5
1302,5
1333,5
1933,5
2014
2225
2600
CIRCULATING
1 cm
10 cm
QDW 35
FLANGE
K35-1
K35-2
FLANGE

FIG. 4a.



STRAIGHT SECTION 50
HT COND
HT COND
HORIZONTAL
EJECTED 50-50 %
P̄
0
375
586
666,5
1266,5
1297,5
1897,5
1974
2225
2600
CIRCULATING
1 cm
10 cm
QFW 50
FLANGE
K 50-1
K 50-2
FLANGE
QDW 51

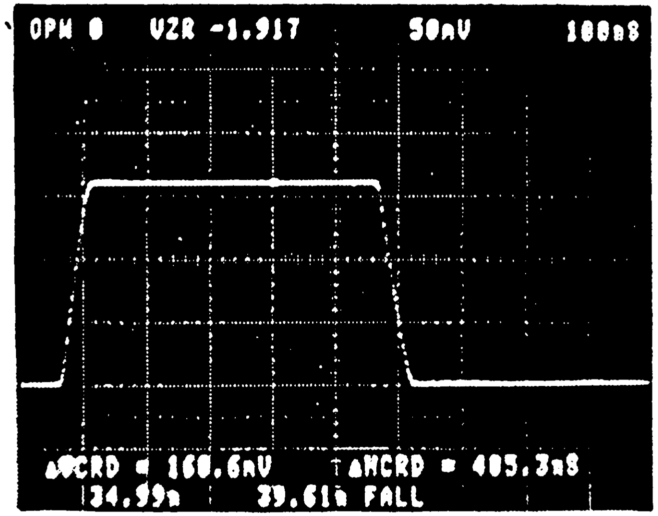
FIG. 4b.



K35
VERTICAL
P
CIRCULATING
QDW35
K35-1
K35-2
QFW36
K50
P
QFW50
K50-1
K50-2
QDW51
1cm
10cm

FIG. 5.

<u>FIG. 6</u> Pulse generator



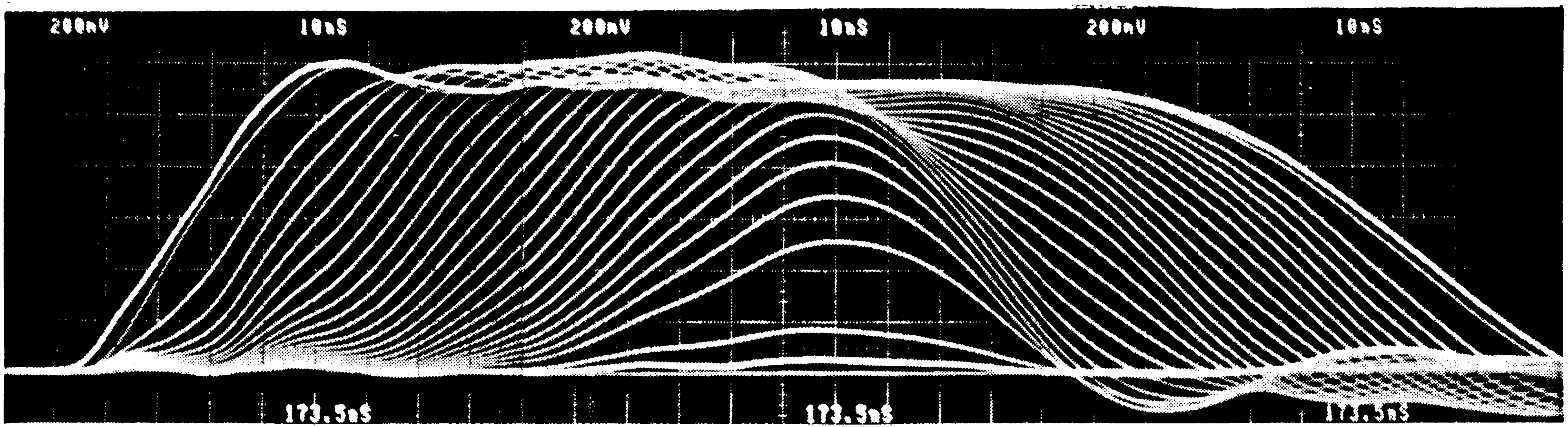
<u>FIG. 7</u> L.V. Applied pulse.

T_R = 35 ns

T_F = 40 ns

A = 1,6 V

W = 500 ns



<u>FIG. 8</u> Pulse propagation
L.V
K50-2

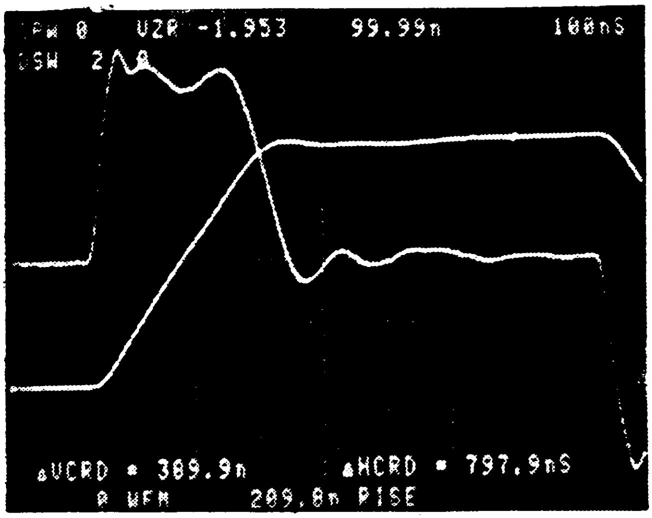


FIG. 9 $V_1 - V_{25}$ and $\int (V_1 - V_{25})dt$ L.V.

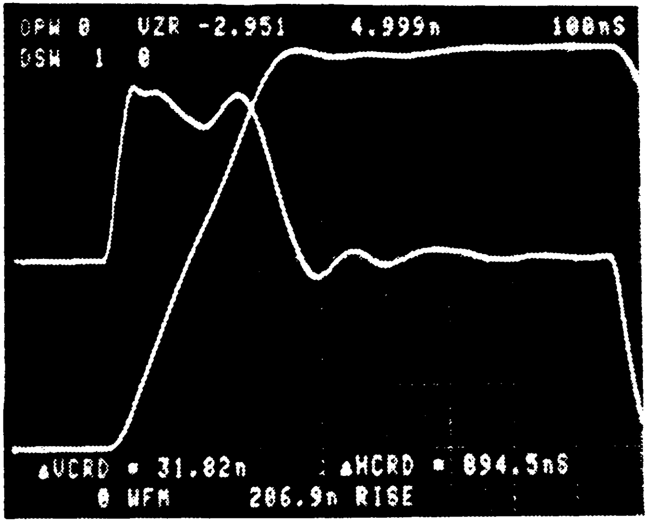


FIG. 10 $\frac{d\phi}{dt}$ and $\int Bdl$ L.V. measured with strip line probe.

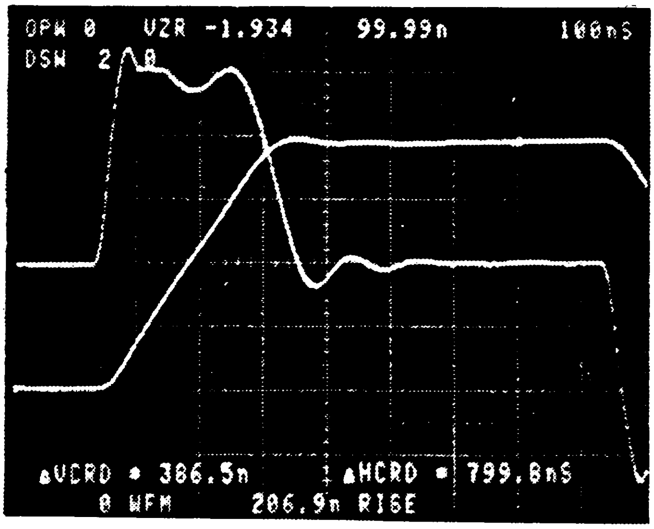


FIG. 11 $\frac{d\phi}{dt}$ and $\int Bdl$ L.V.

C_{IN} = 470 pF

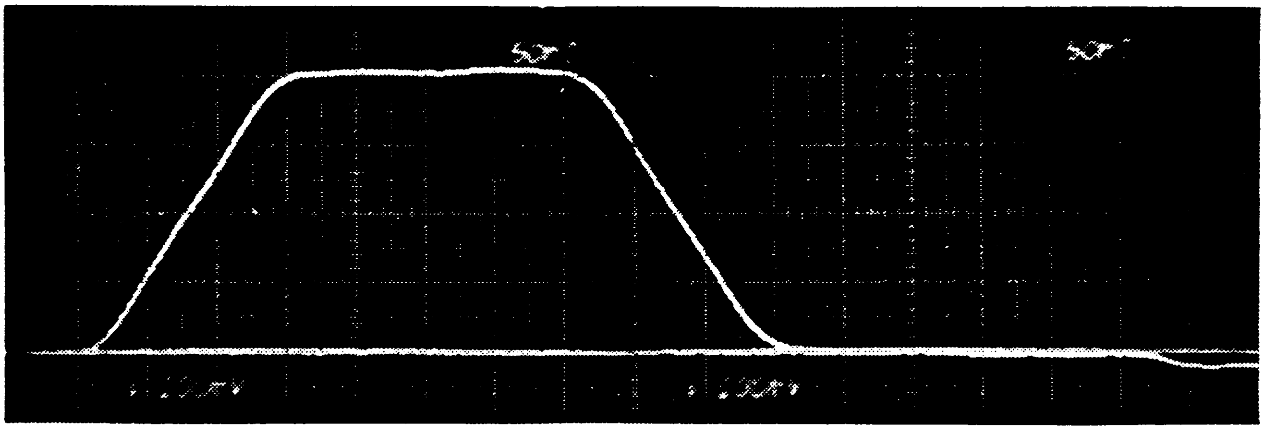


FIG. 13. $\int Bdl$ H.V.

K35-2

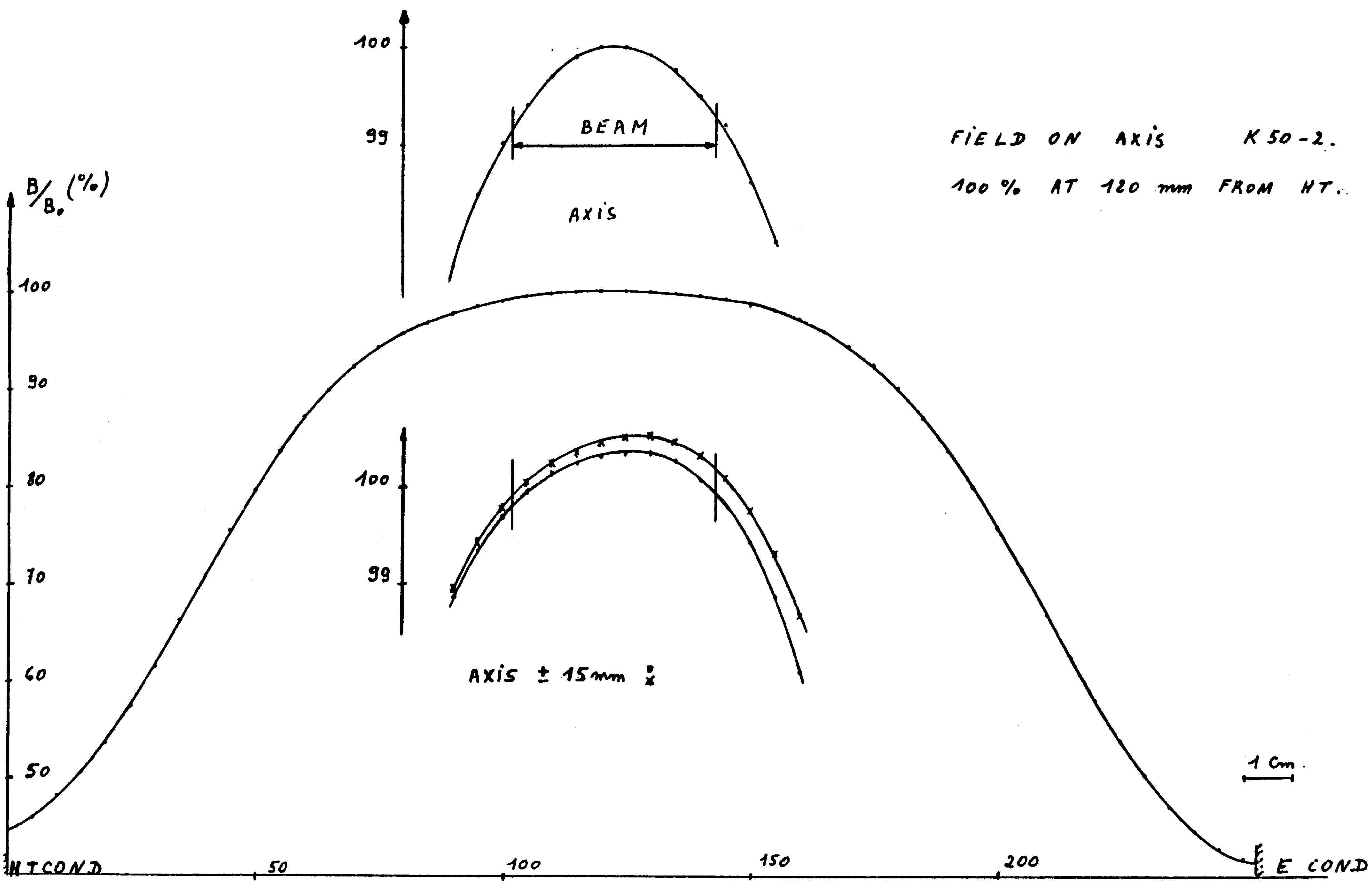

FIELD ON AXIS K 50-2.
100 % AT 120 mm FROM HT.
B/B₀ (%)
100
90
80
70
60
50
100
99
BEAM
AXIS
100
99
AXIS ± 15 mm ˙x
1 Cm
HT COND
50
100
150
200
E COND

FIG. 12 a.

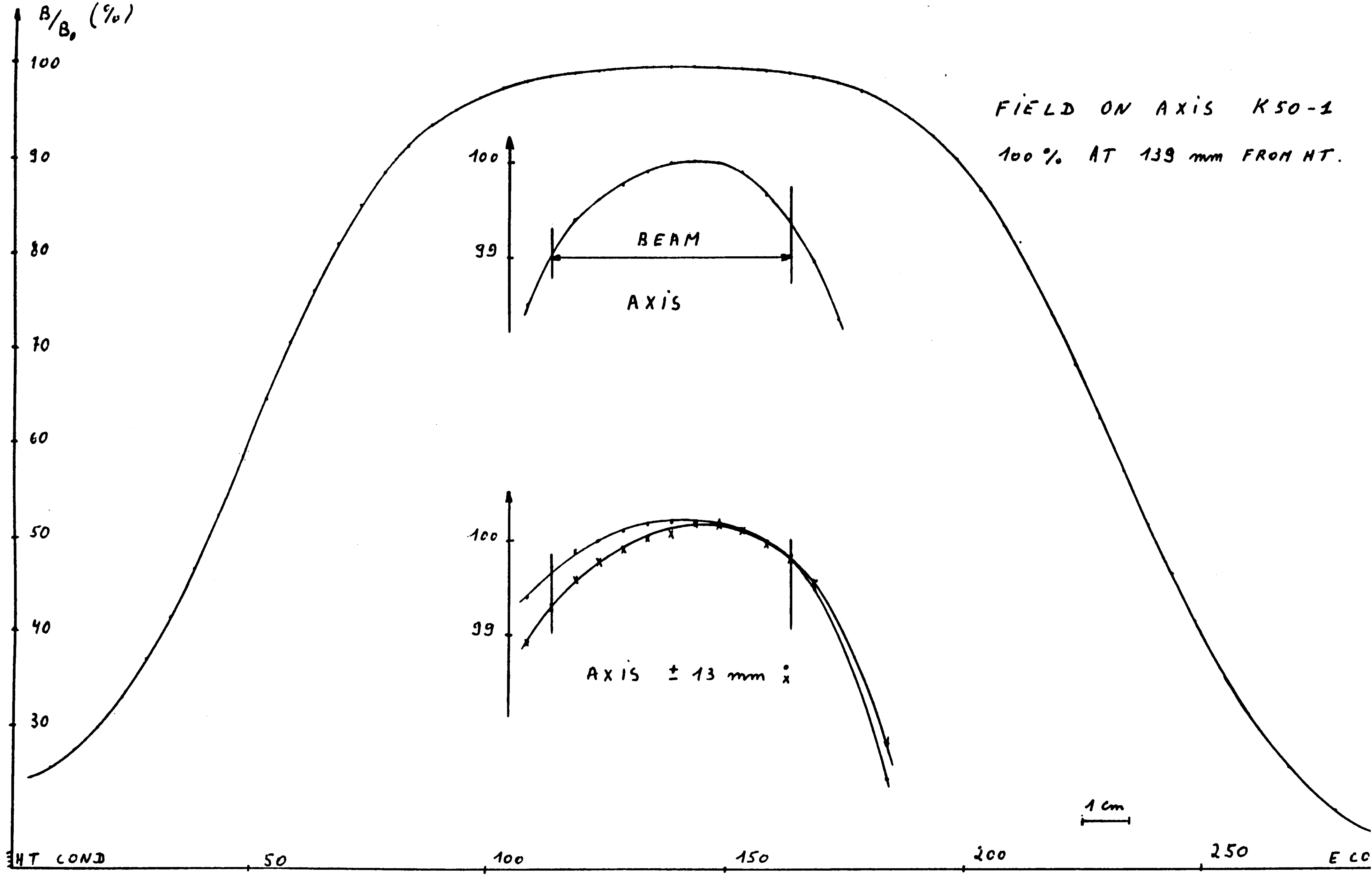

B/B0 (%)
100
90
80
70
60
50
40
30
FIELD ON AXIS K50-1
100 % AT 139 mm FROM HT.
100
99
BEAM
AXIS
100
99
AXIS ± 13 mm
1 cm
HT COND
50
100
150
200
250
E CO

FIG. 12 b.

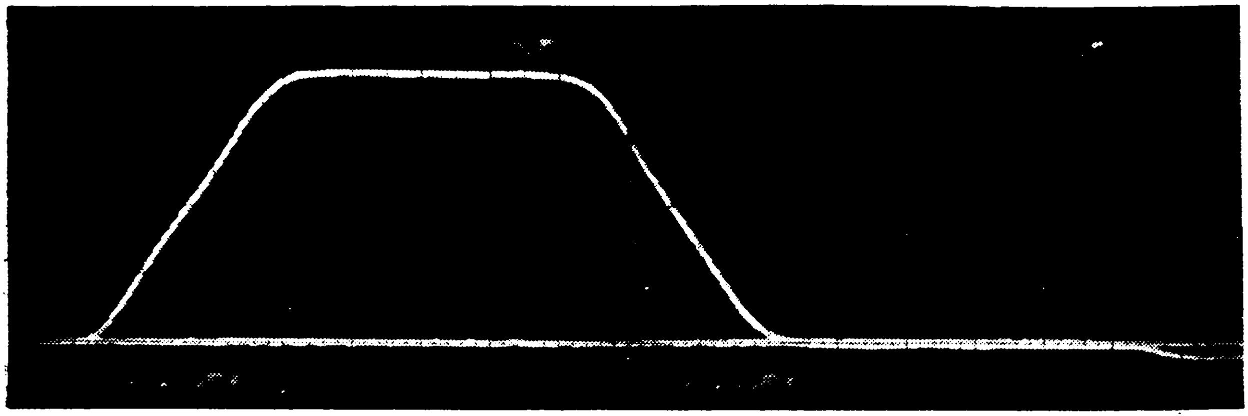


FIG. 14 $\int Bdl$ H.V. C_{IN} = 470 pF. = C_{OUT}
K35-2

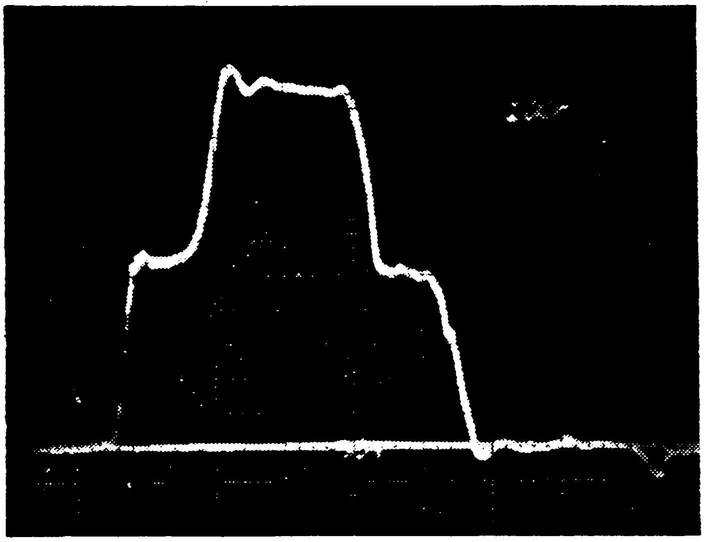


FIG. 15 Input current K35-2
C_{IN} = 470 pF.
= C_{OUT}

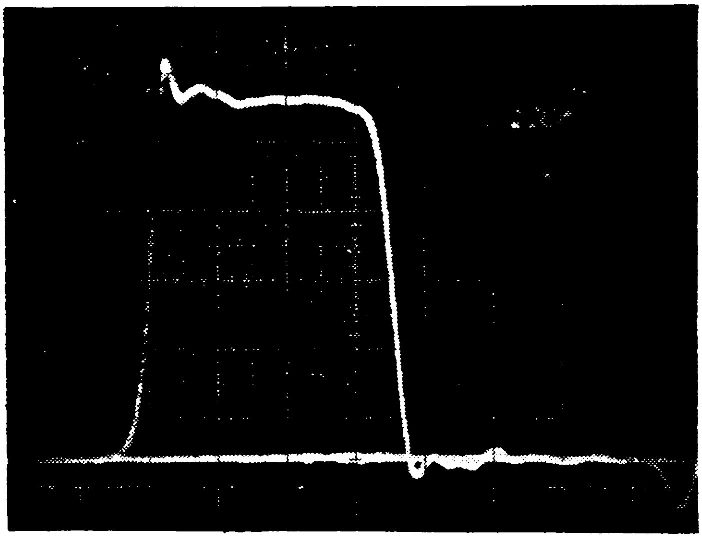


FIG. 16 S/C current
K35-2
C_{IN} = 470 pF.
= C_{OUT}

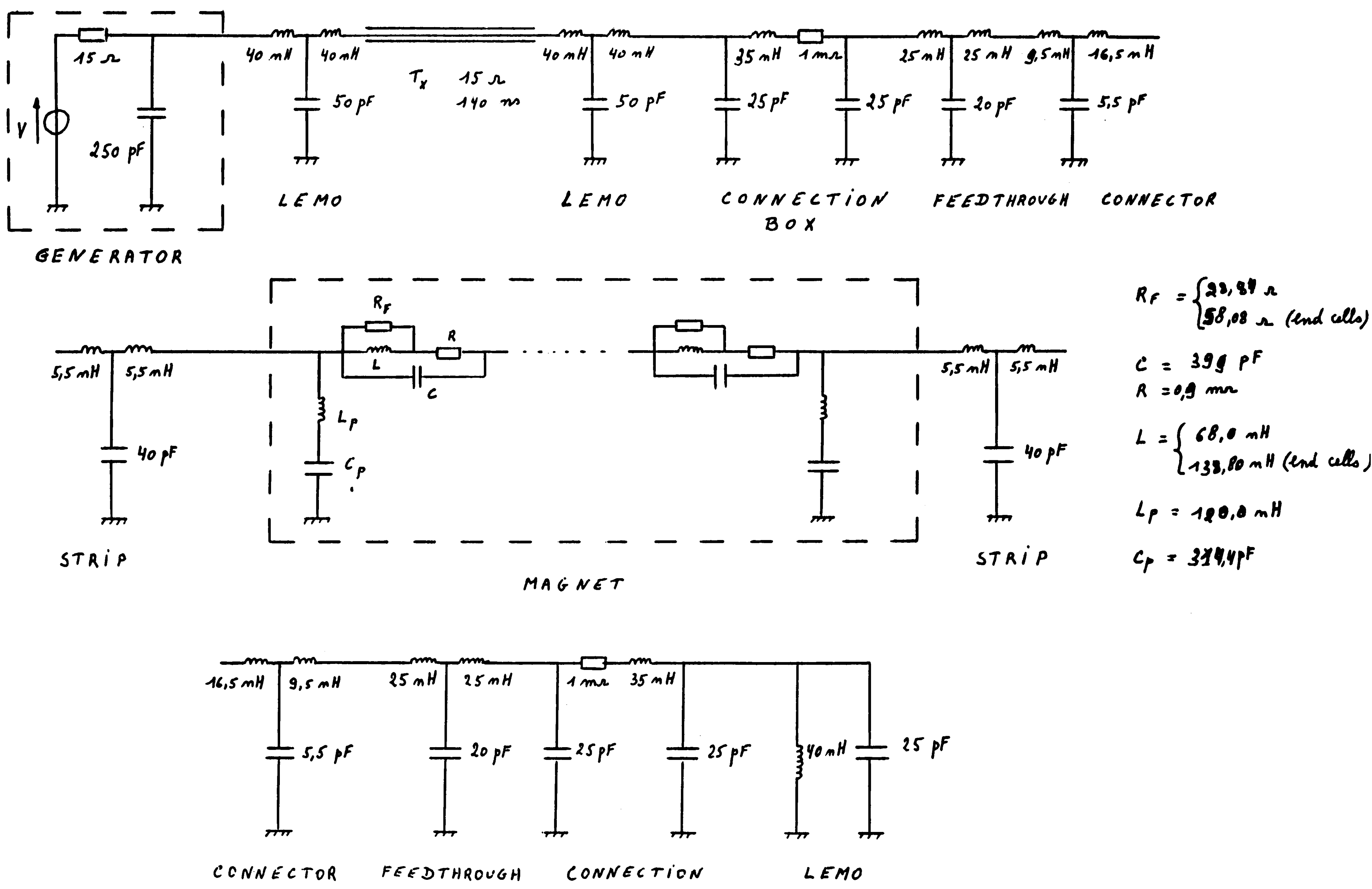


FIG. 17 Equivalent circuit of K35-2 in the tank.

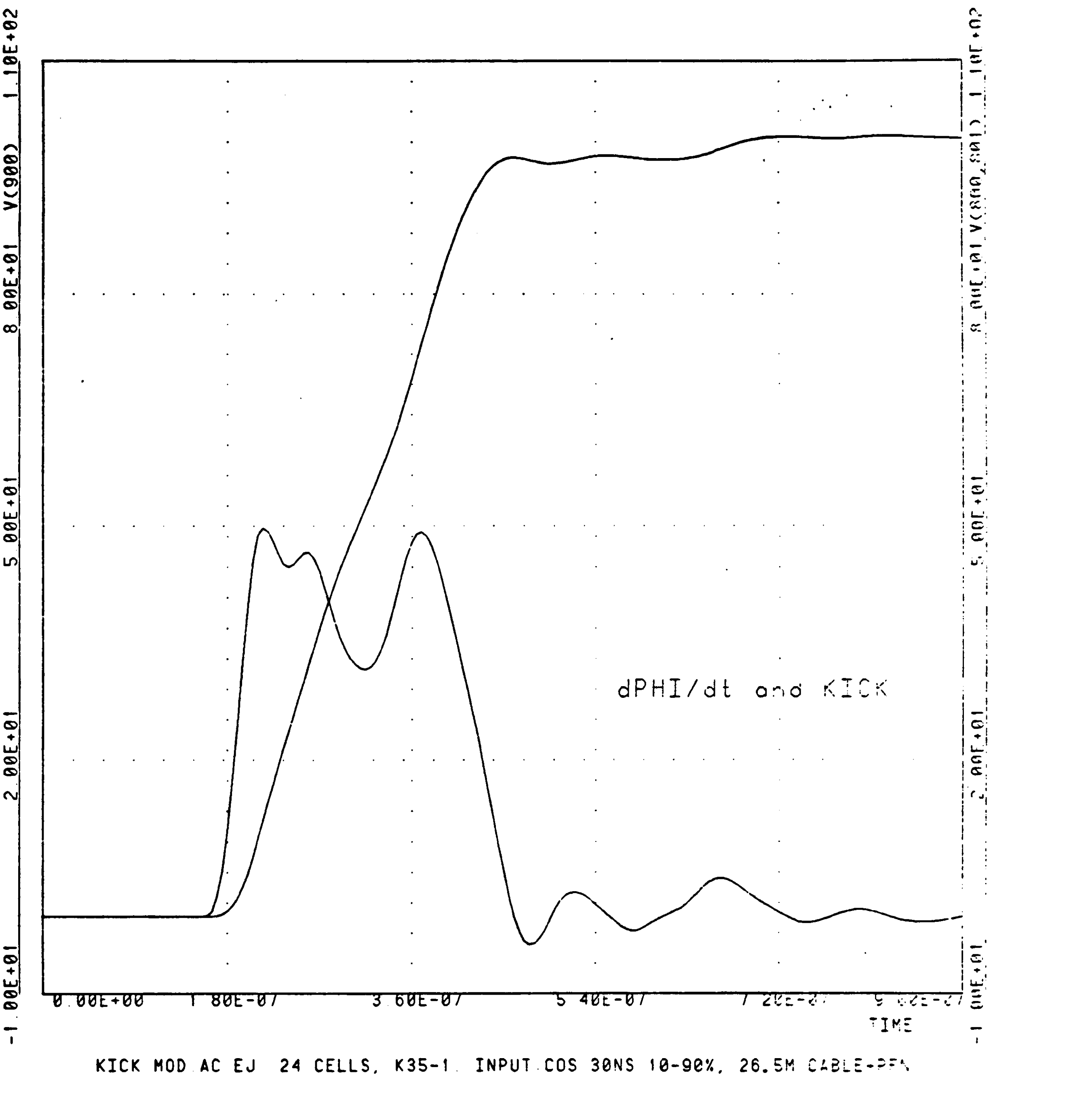


FIG. 18 **SPICE results.**

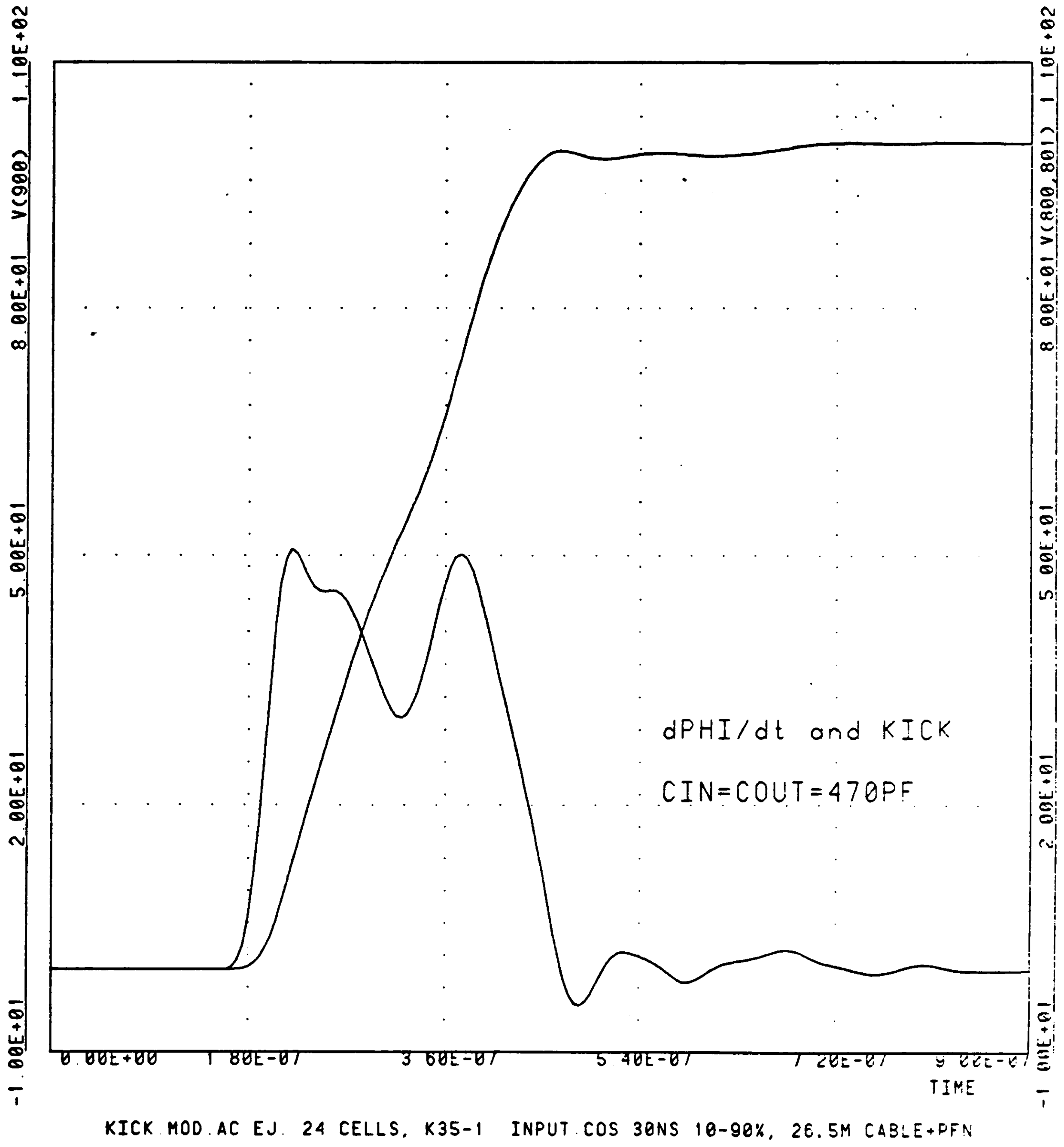


FIG. 19 **SPICE results.**

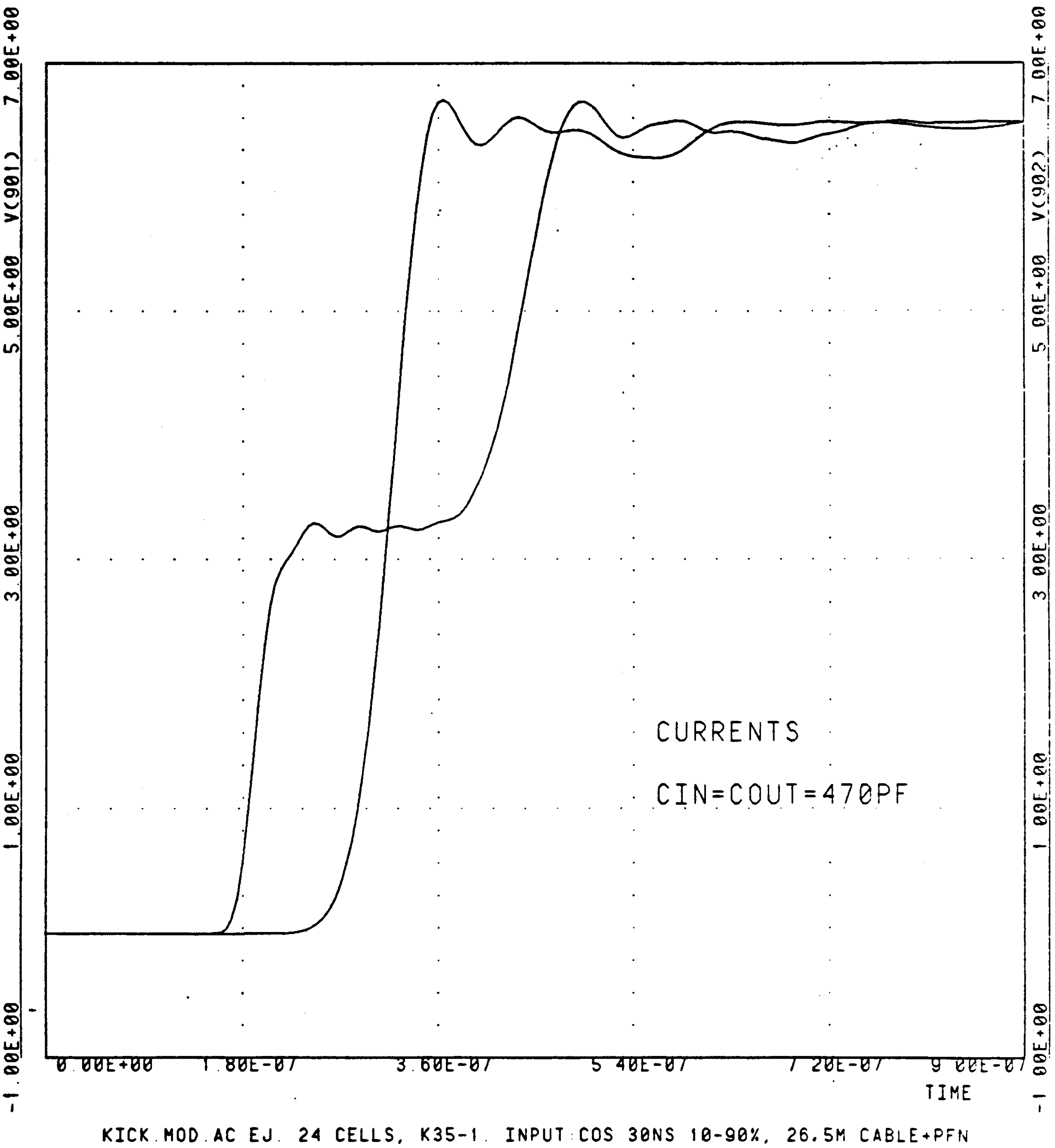


FIG. 20 SPICE results.