EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

PS/BT/Note 87-9
23.10.1987

AC INJECTION KICKER FOR AA COMPLEX

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Summary

Antiprotons coming from the target area via the 3.5 GeV/c injection line, are kicked into the AC ring by six delay line type kicker modules short-circuited at one end.

This note describes the system and gives the useful parameters to run it correctly.

Geneva, Switzerland

I. INTRODUCTION

This note describes the kicker system built for the injection of $\bar{p}$ from the target area into the AC ring of the AA complex.

The main part of it will give the relevant details about magnets but a summary of the pulse generator characteristics described in Ref. [1] will also be treated.

II. BEAM REQUIREMENTS

Coming from the target area via the 3.5 GeV/c injection line, five bunches of 30 ns maximum length, center spaced by 104.85 ns have to be injected into the AC ring. Rotation time being 629.14 ns, this allows a gap of 179.7 ns for the kick fall time (95-5)%, assuming that 95% of the full kick will touch the last particles of the fifth bunch to be injected and that the first particles of the first bunch injected will be retouched by 5%.

The kick flat-top must be at least 480 ns with a uniformity of $\pm$ 1%.

The deflection angle requested is θ = 17.588 mrad for a 240 π mm.mrad, $\Delta p/p = \pm$ 3% injected beam ($\int Bdl$ = 0.2097 T.m).

A field uniformity of $\pm$ 1% is also requested inside the useful aperture.

Straight sections 55 and 56 have been chosen to place the kicker tanks (Fig. 1).

III. KICKER SYSTEM

A. Magnet Design

According to the beam dimensions [2], the kick strength required, the kick fall time and the space allowed, it appeared that it was not possible to achieve the kick strength with terminated 15 Ω magnets as it was for the AA [3]. Furthermore, the 15 Ω magnet impedance could not be changed because of the necessity to re-use the old AA injection generators (with a minimum of changes), a solution which was the most economical and realistic. After exhaustive development work [1], the decision of using short-circuited magnets was taken. This solution provides twice the current and hence twice the kick strength for the same PFN voltage but implies some penalties as we shall see further.

Due to the large beam spread in the sections and the fall time allowed, it has been necessary to split the kicker into six modules. These are placed in two tanks, each containing three different modules. The tanks are located symmetrically around a focussing quadrupole.

The magnet construction follows closely that used for AA injection kickers (transmission line magnets). The main difference is the frame which has been made of Antico for weight reasons and because the vacuum pressure required in AC is not as low as in AA. Whilst the tanks are not bakeable, magnets can be baked to 300°C if necessary. The modules are closed C-apertures. They are constructed with 20 and 27 cells respectively, and have a maximum of similar or identical components. A photo of a 27 cell magnet 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, and verified by RF measurements on a model magnet. A plot of flux lines given by POISSON for K55-2 module is shown in Fig. 3. A plot of field uniformity (computed with MAGNET) and the beam envelope (assumed rectangular) at magnet entry and exit is given in Figs. 4a to 4g.

Table 1 summarizes the main magnet characteristics.

Figs. 5 and 6 show the magnet positions 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.7). This last feature permits to reverse the kick direction by reversing the current direction in the magnet, at the premium that roughly 5 ns are lost in additional travelling time for the wave to reach this short-circuit, be reflected and fill the magnet a second time.

Another penalty is the existence of negative current in the dump switch thyratron. The CX1671A hollow anode tube used can conduct easily this inverse current but it takes some time and generates an important negative reflection which travels through the magnet and affects the kick tail. The use of a CX1671X tube, associated with adequate filtering, reduces the reflections drastically. Unfortunately, this new tube type is not yet reliable and needs some more tests and improvements. It has thus not been installed in the AC generators yet.

Normal operation voltage at nominal deflection angle of 8.794 mrad per tank with six generators is 64 kV. Any five out of these six generators at 77 kV will also suffice. Maximum possible operating voltage is 80 kV, thus providing little but acceptable margin.

C. Performance

a) Low voltage measurements

As for AA injection magnets, these measurements have been performed with a HP pulse generator providing a pulse as shown in Fig. 8. The magnet was short-circuited at one end. The propagation of the leading edge of this pulse through the 27 cells of *magnet K55-1 is shown in Fig. 9. The integrated field along beam axis (∫Bdl) and dΦ/dt are shown in Figs. 10 and 11 (K55-3). The time to get to 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 (Fig. 12) (K55-3). The field uniformity measured with a strip line probe is shown in Fig. 13 (K55-3).*

b) High voltage measurements

After bake-out to 300°C, magnets have been tested at high voltage in a test tank to evaluate their performance as in future operation. The test voltage was 80 kV corresponding to a current of 5200 A. A typical ∫Bdl (K55-3) photo is shown in Fig. 14. A C1671X dump switch was used in the generator. With a CX1671A DS, the results are not so good because of the tube's inferior acceptance of negative current. A negative kick with a peak value of 7% appears in the tail (Fig. 15). This problem could be avoided by using a double cathode switch, but the cost would be very high because main and major parts of the generators need to be redesigned. However, development work is continuing to obtain a thyratron switch with superior negative switching performance.

In order to match the system and compensate the negative coupling between cells, 680 pF capacitors have been connected to both magnet ends. The ∫Bdl fall time measured from Fig. 16 is 186 ns (95-5)%. Current at magnet entry and exit measured with a PEARSON transformer type 110A are shown in Figs. 17 and 18. SPICE calculations give very similar results (Figs. 20, 21, 22) with the equivalent circuit of Fig. 19.

D. Magnet Installation in K55-K56

After an individual 300°C bake-out cycle, three magnets are positioned on a common support beam and then introduced into the tank [4].

After pumping, they have been pulsed again at 80 kV some 10^5 shots before final installation in the AC ring. Since the end of July 1987, they have been operationally used both with proton and antiproton beams.

References

[1] A pulse generator for short-circuited delay line magnet excitation, D. Fiander et al, CERN/PS/BT 85-35, 4.6.1985.

[2] ACOL injected and ejected beam sizes deduced from a perturbation method based on "orbit" data, M. Martini, PS/ACOL/Note 28, 29.5.1985.

[3] AA injection kicker system for AA complex, K.D. Metzmacher, L. Sermeus, PS/BT/Note 87-5.

[4] Injection and ejection systems at straight sections 55/56 and 35/50 of the AC, G. Betty, PS/ML/Techn.Note 85-10, 15.7.1985.

[5] 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, 14.9.1986.

[6] R. Sherwood, Private communications.

List of drawings

Ensemble K55-3/K56-1	PS-C-0728-22-0
Ensemble K55-2/K56-2	PS-C-0729-22-0
Ensemble K55-1/K56-3	PS-C-0730-22-0
Straight Section 55	PS-C-0792-22-1
Straigth Section 56	PS-C-0772-22-1

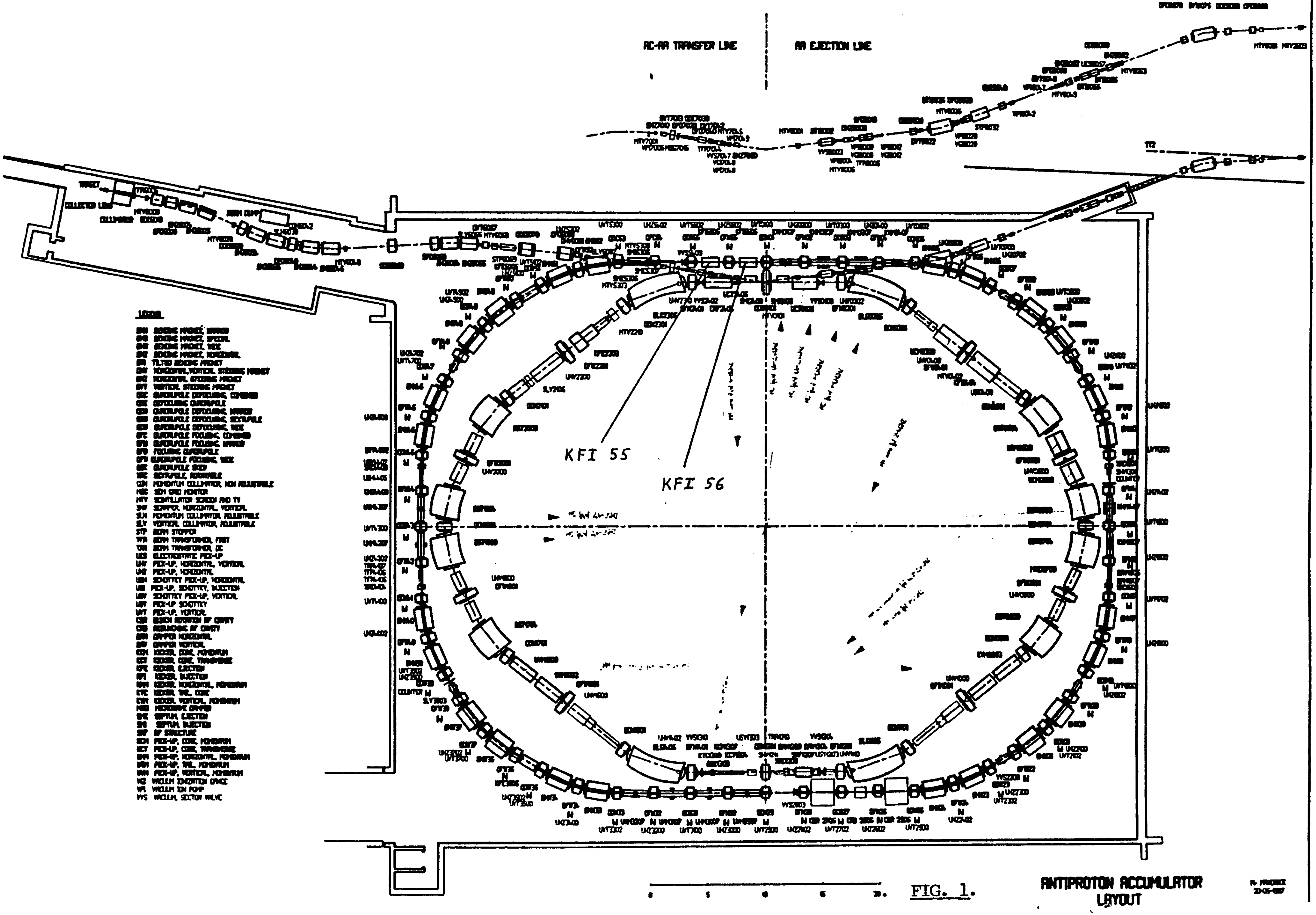
Distribution

AA Scientific Staff
BT Scientific Staff

TABLE 1. AC Injection

Data	Units	55-3 56-1	55-2 56-2	55-1 56-3
w	mm	140	140	140
h	mm	72	82	95
n	cells	20	20	27
l_{eff}	mm	504	504	672
V_{PFN}	kV	80	80	80
Zo	Ω	15	15	15
I	A	5200	5200	5200
∫Bdl	G.m	457.2	401.6	462.2
θ	mRad	3.835	3.367	3.875
L	μH	1.23	1.08	1.25
C	pF	5475	4608	5530
T_M	ns	82.1	72.1	83
B_{air}	G	907	797	688
$B_{fer\ mid\ cell}$	G	2065	2070	2086
$B_{fer\ end\ cell}$	G	3100	3100	3130
w_{fer}	mm	80	70	60
V_{fer}	cm^3	17000	14600	16700
M_{fer}	kg	90	78	88.5
A_M	mm x mm	435x722		
l_M	mm	524	524	692
l_{tank}	mm	2102		

Remanent kick strength at 80 kV : 3,85 G.m/tank



AC-AA TRANSFER LINE
AA EJECTION LINE
KFI 55
KFI 56
0
5
10
15
20.
ANTIPROTON ACCUMULATOR
LAYOUT

FIG. 1.

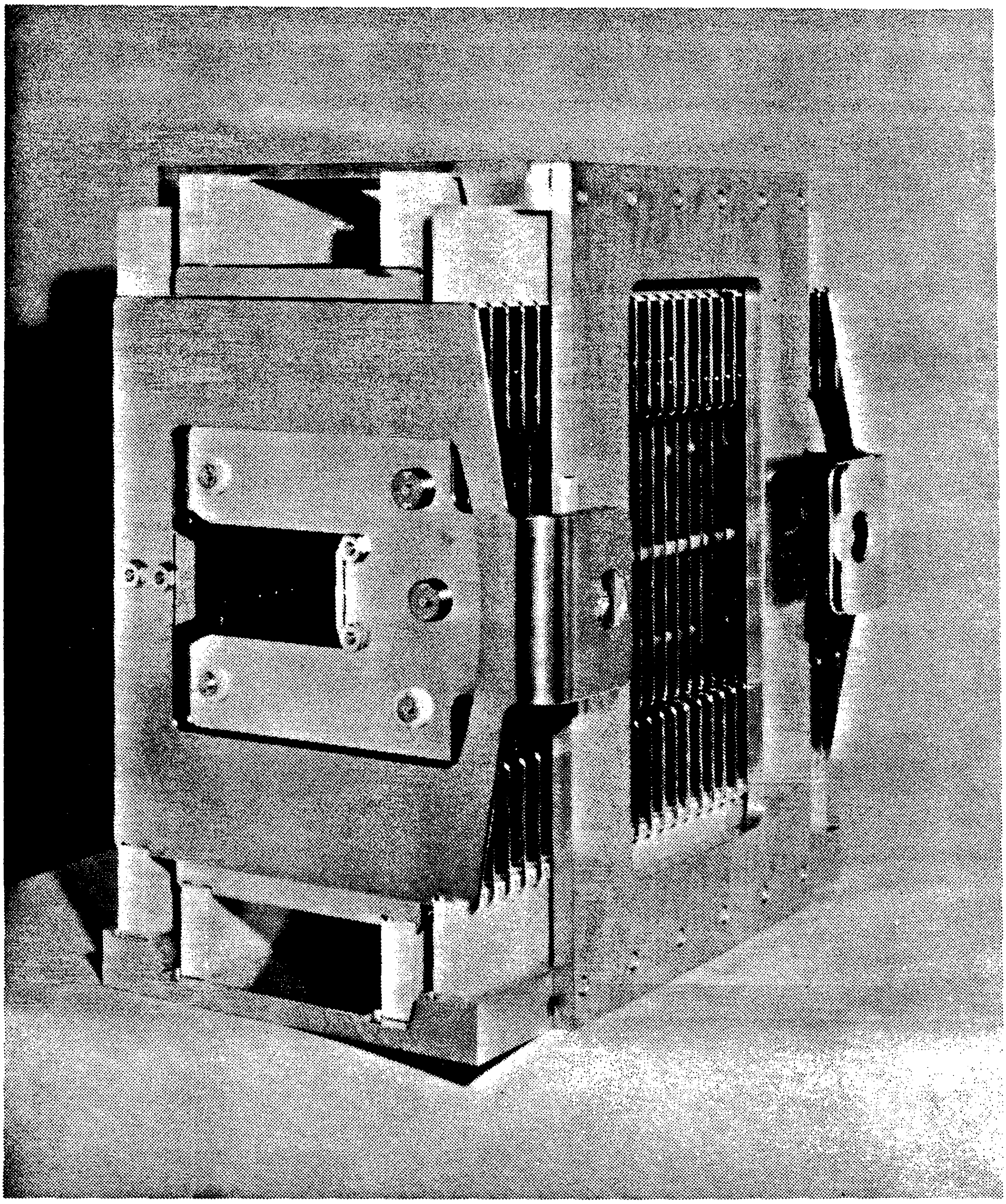
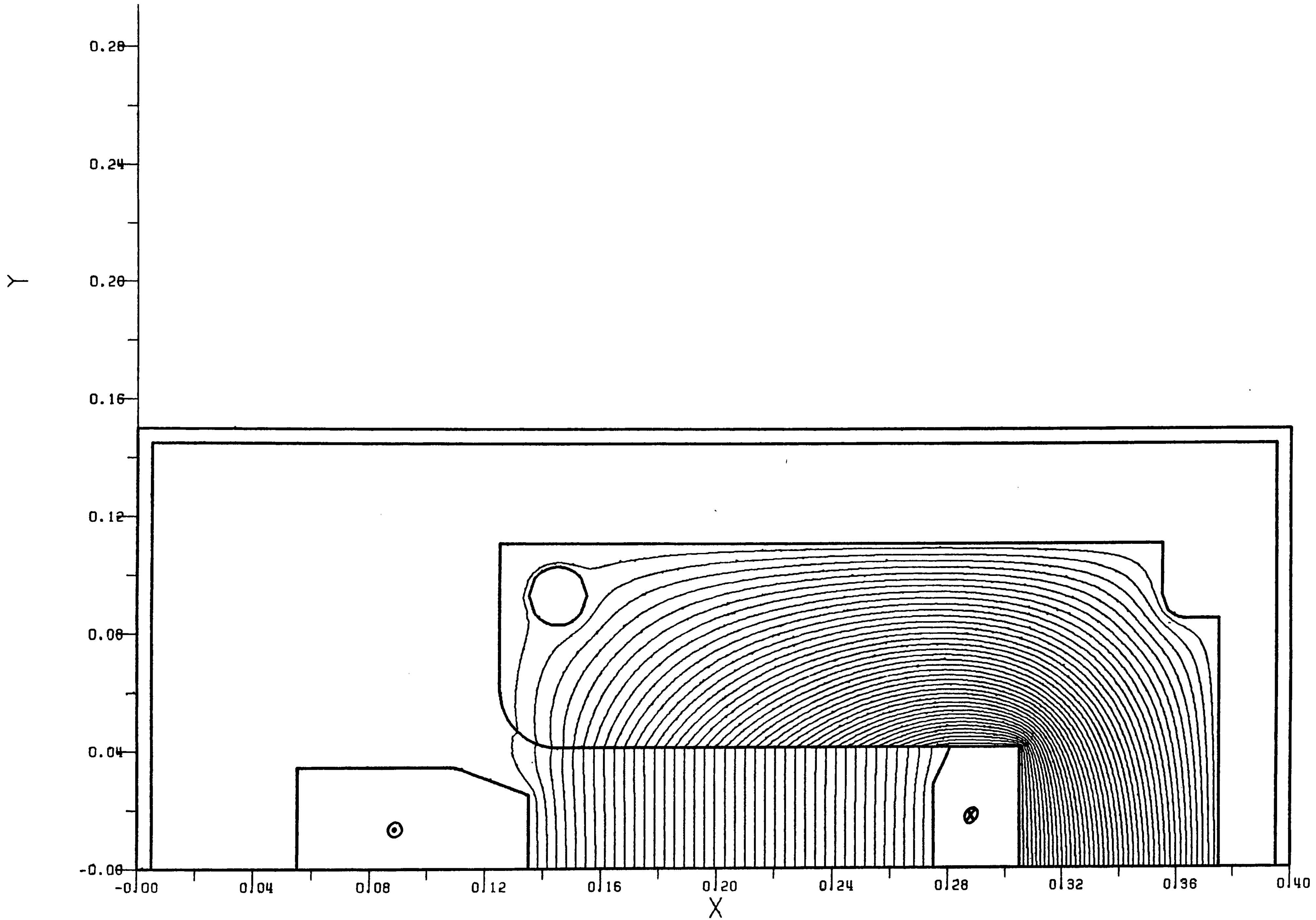


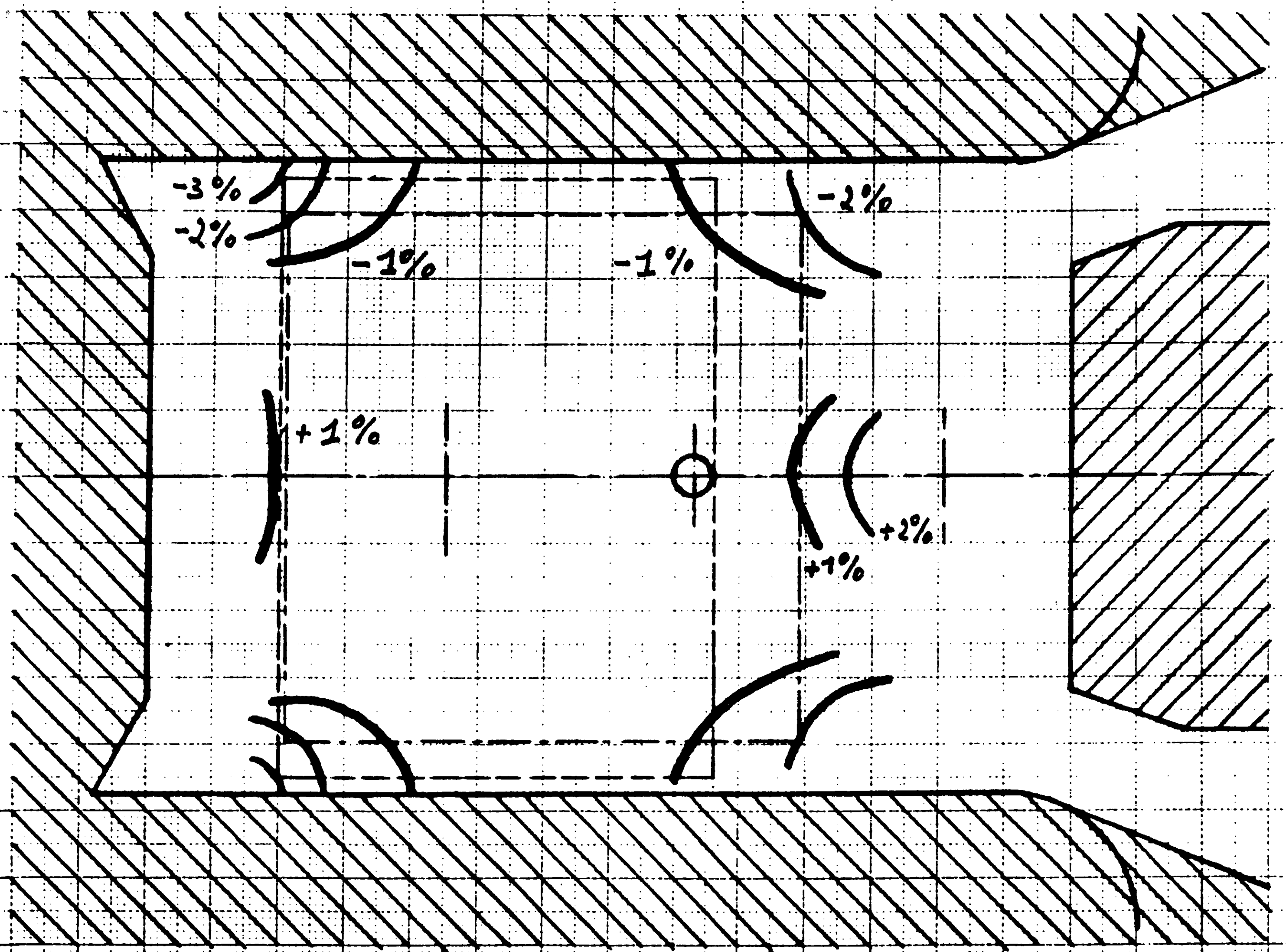
FIG. 2. K55-1 27 cells.



<u>FIG. 3.</u> POISSON plot of flux lines K55-2/K56-2.

55-1

W.h.l. 140 x 95 x 672

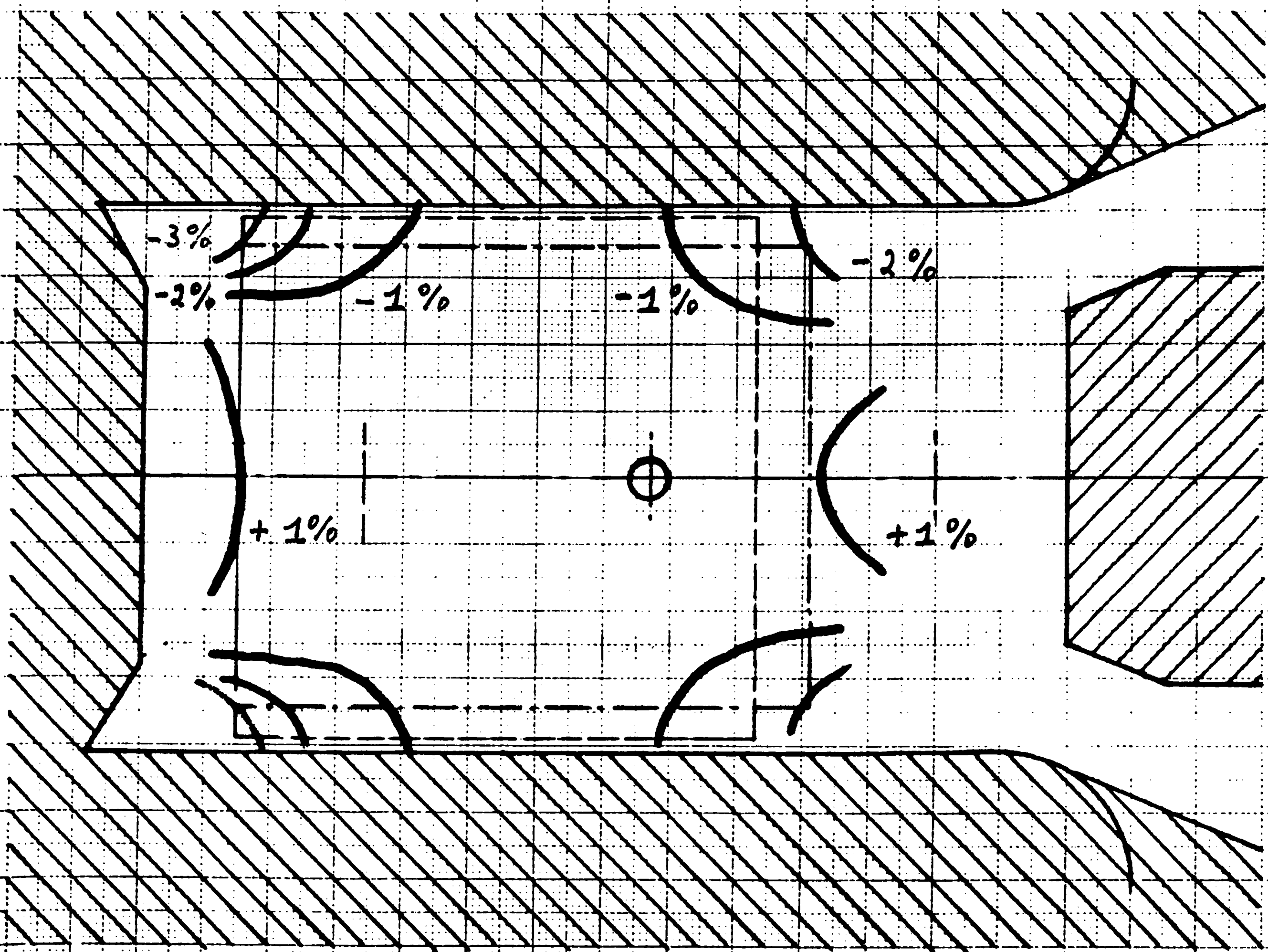


<	± 1%	93,6 %	area
<	± 2%	99,7 %	
<	± 3%	100 %	

FIG. 4 a). Field uniformity in aperture.

55-2

W.h.l. 140 x 82 x 504



< ± 1%	90,0	%	area
< ± 2%	98,8	%	
< ± 3%	99,9	%	

FIG. 4 b).

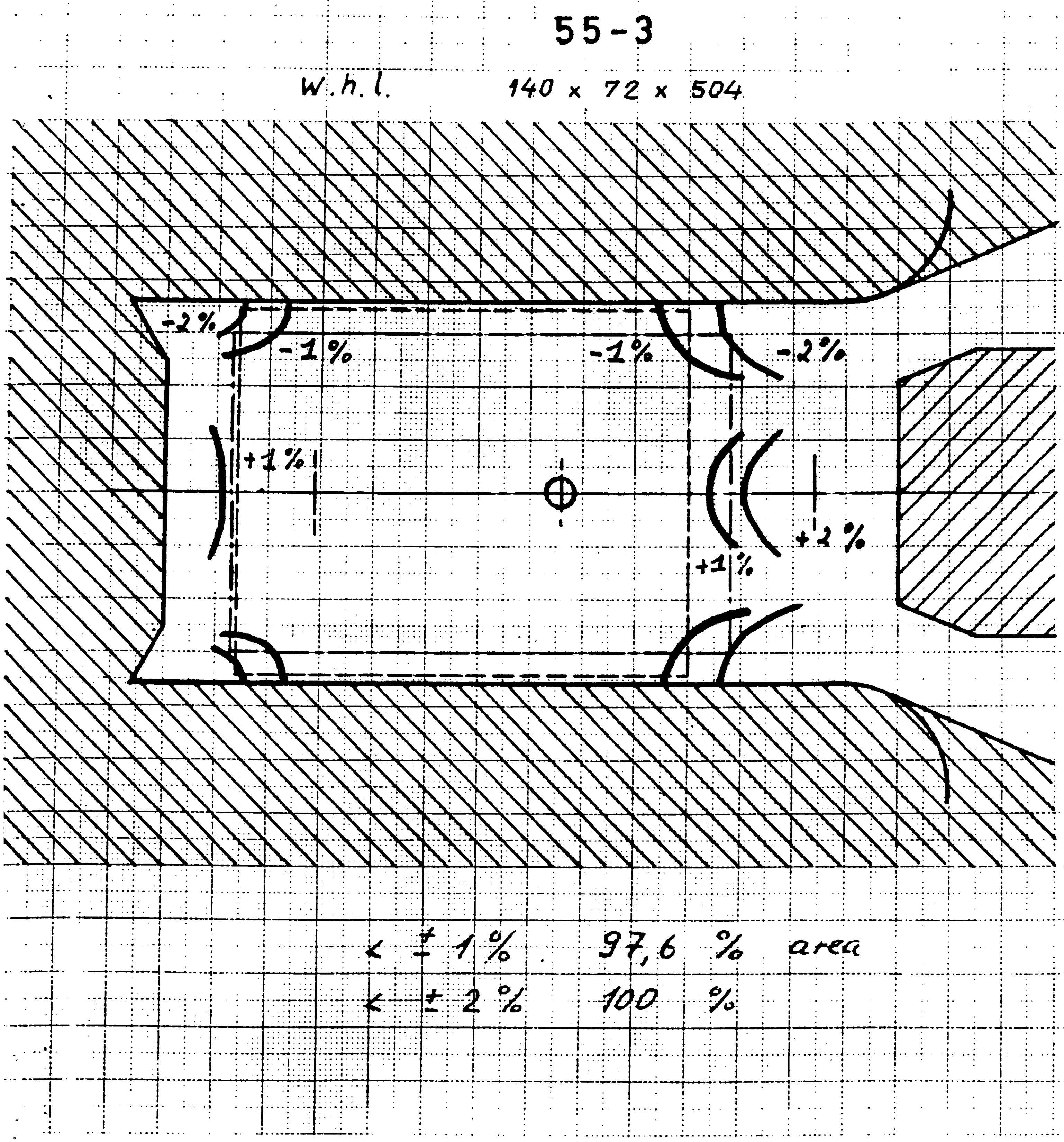


FIG. 4 c).

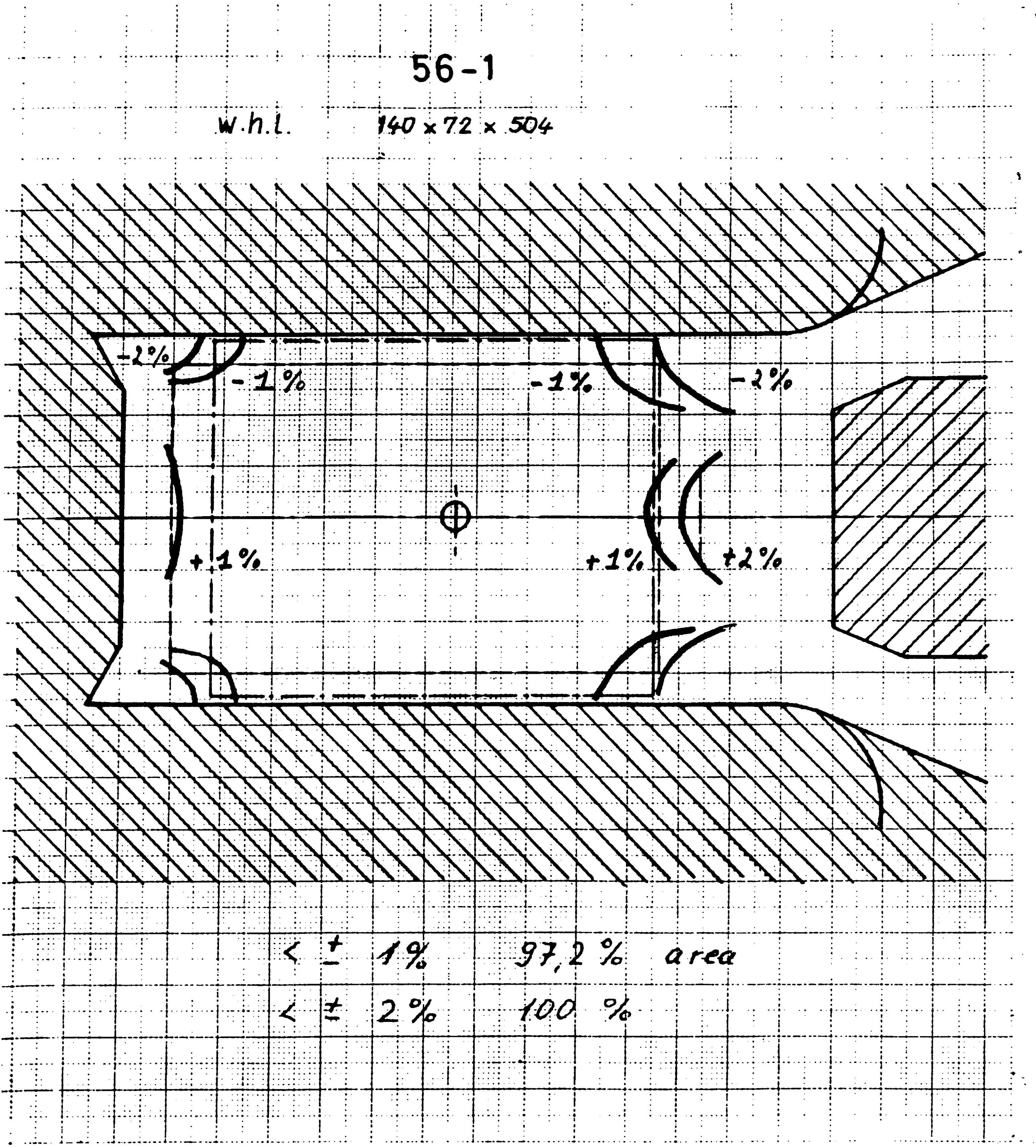
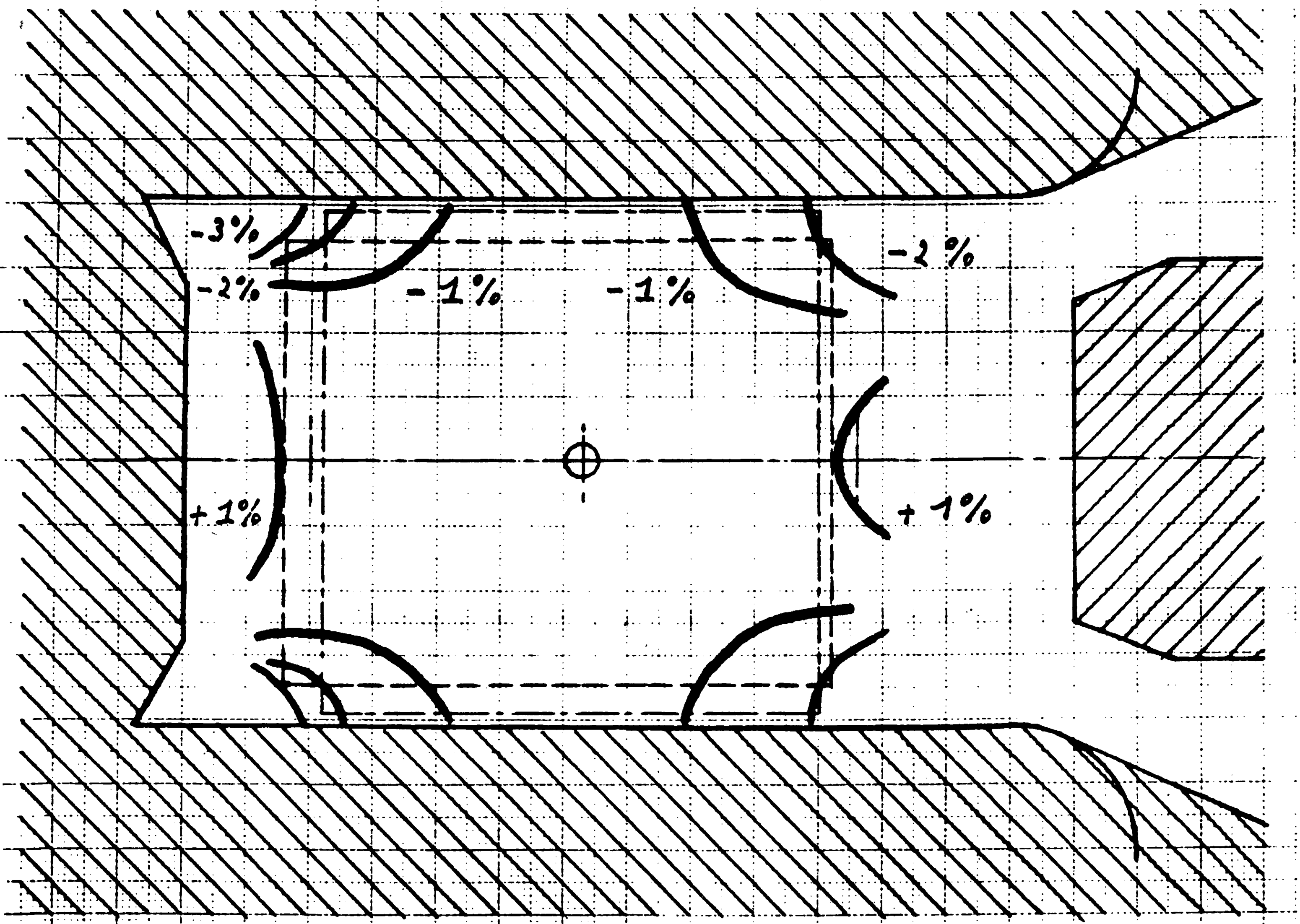


FIG. 4 d).

56 - 2

W.h.l 140 x 82 x 504



< ± 1 %	88,9 %	area
< ± 2 %	99,5 %	
< ± 3 %	100 %	

FIG. 4 e)

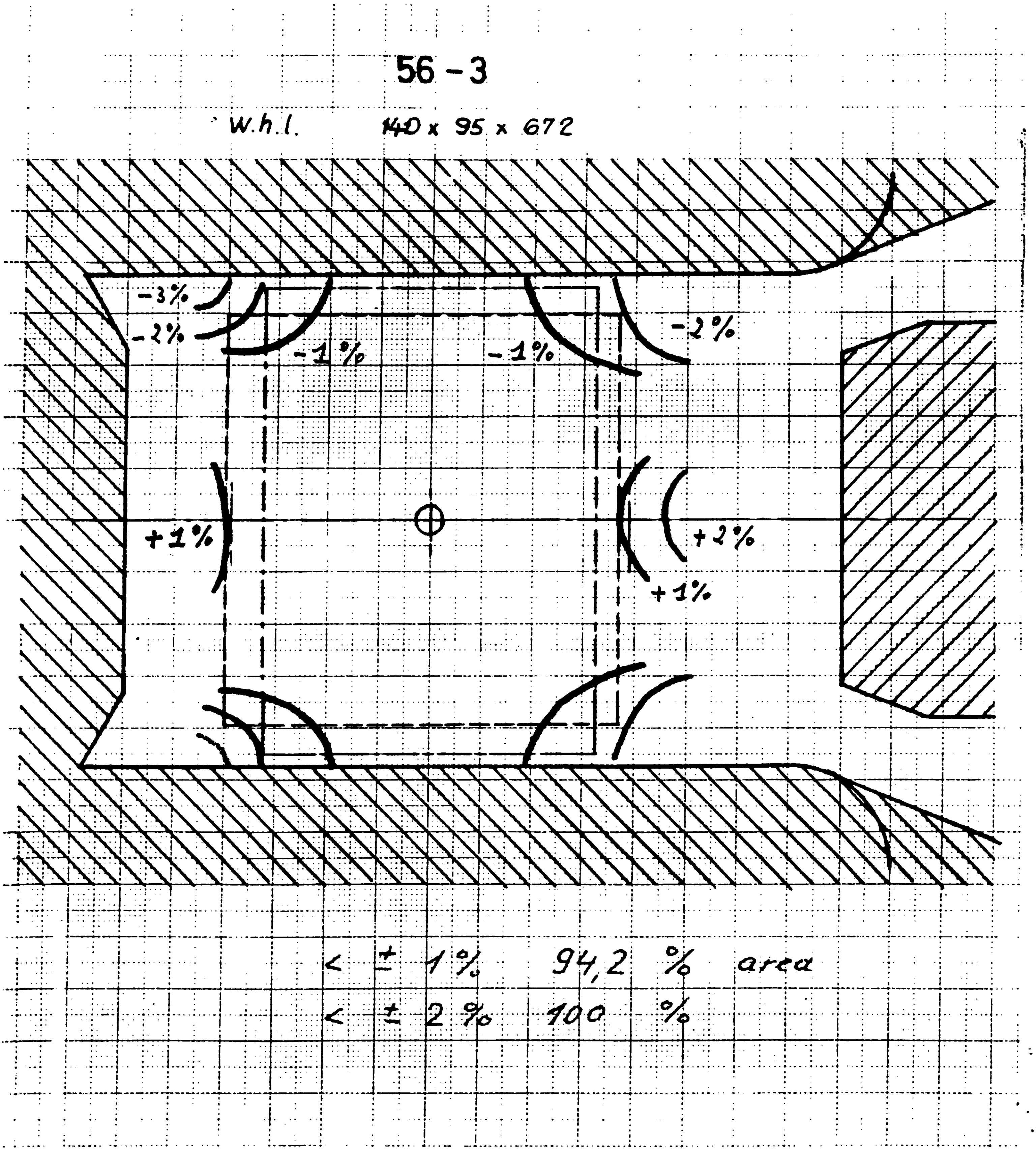


FIG. 4 f).

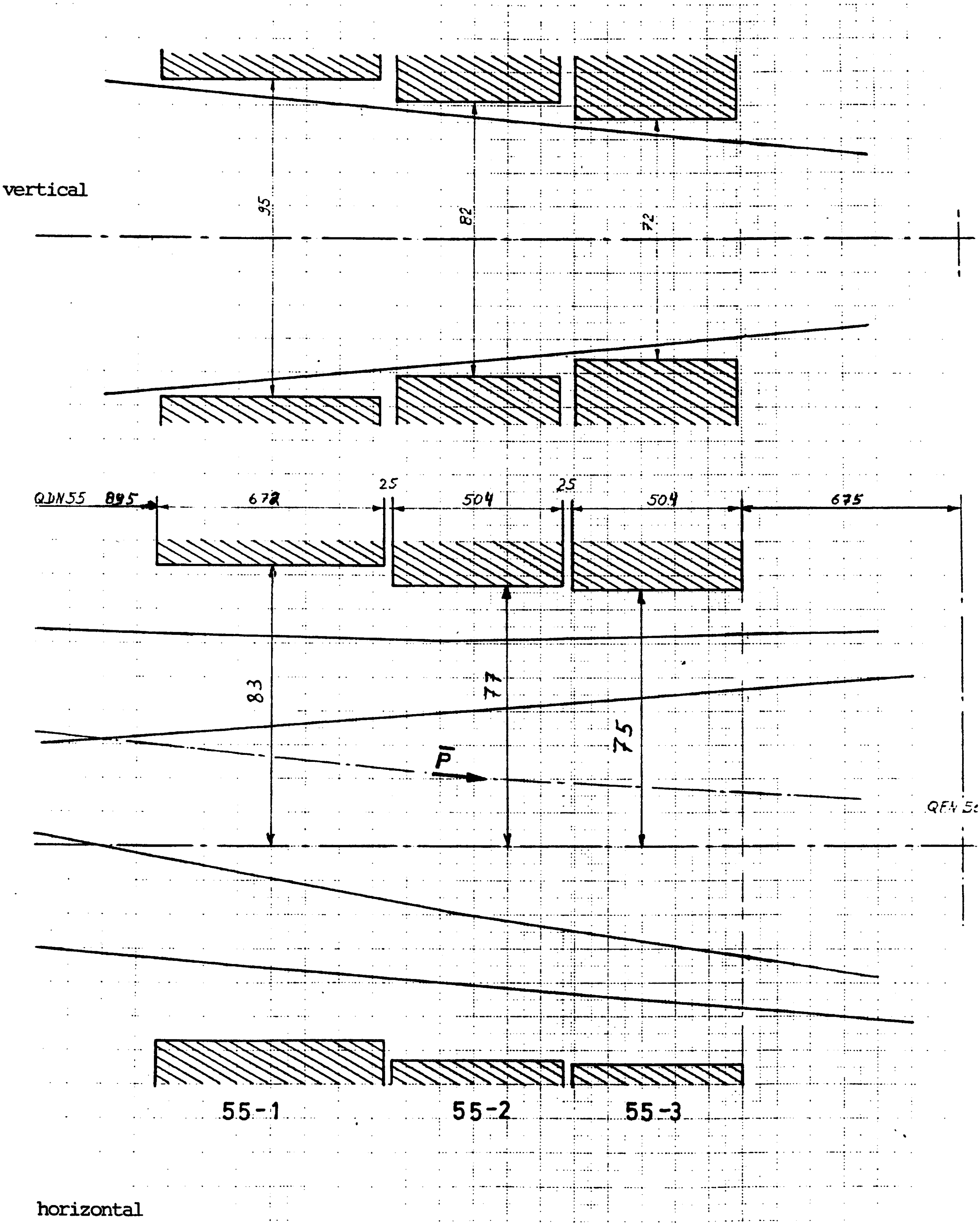


FIG. 5. Tank KFI55 Magnet disposition.

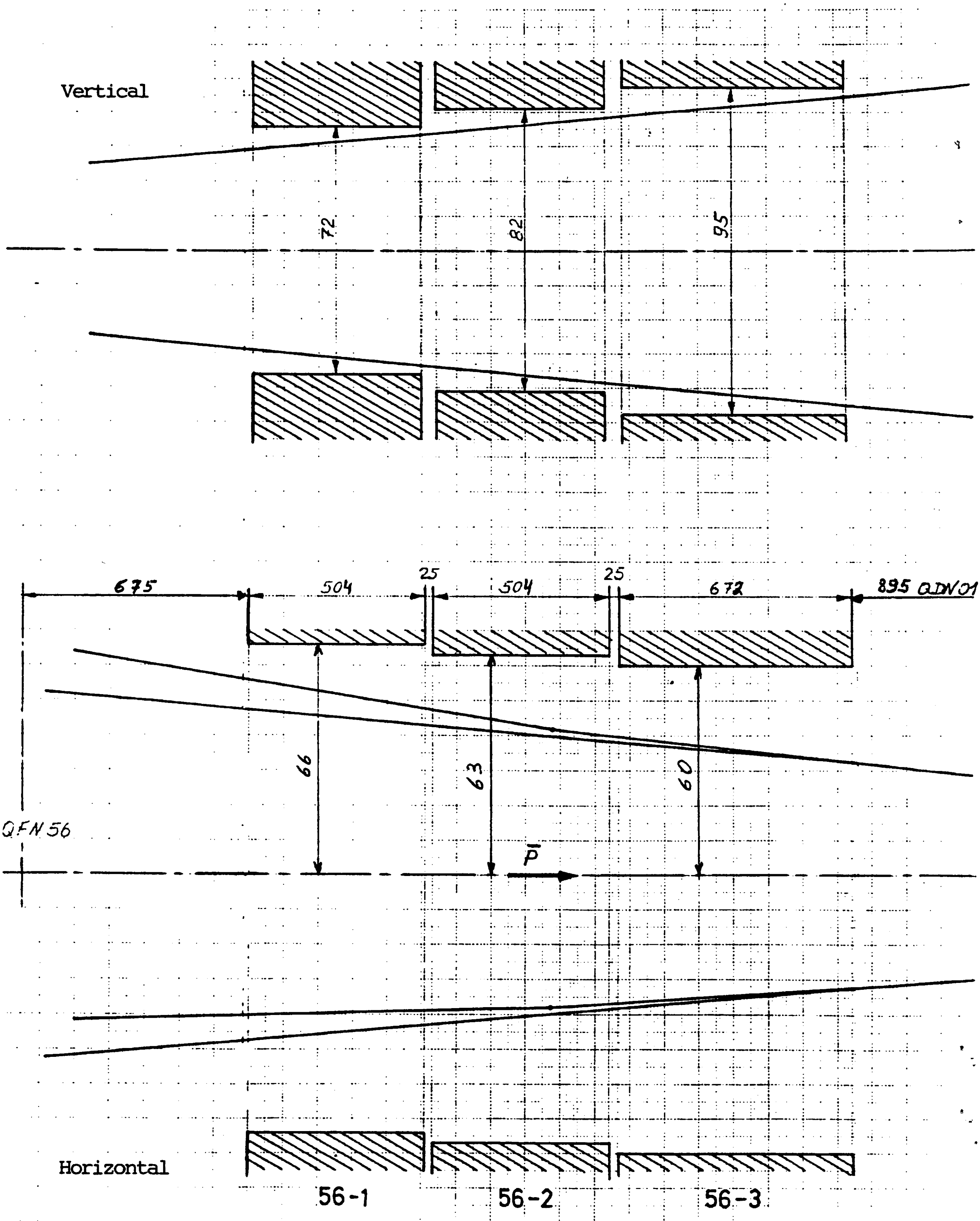


FIG. 6. Tank KFI 56 Magnet disposition.

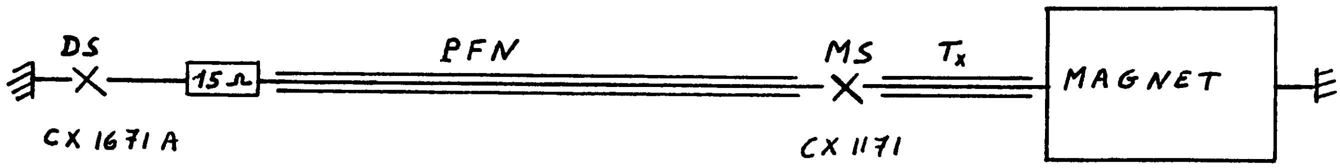


FIG. 7. Pulse generator.

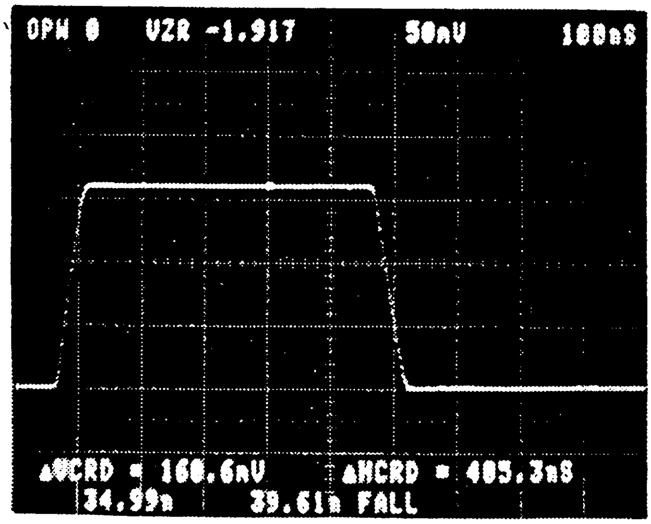


FIG. 8. L.V. Applied pulse

T_R = 35 ns

T_F = 40 ns

A = 1,6 V

W = 500 ns

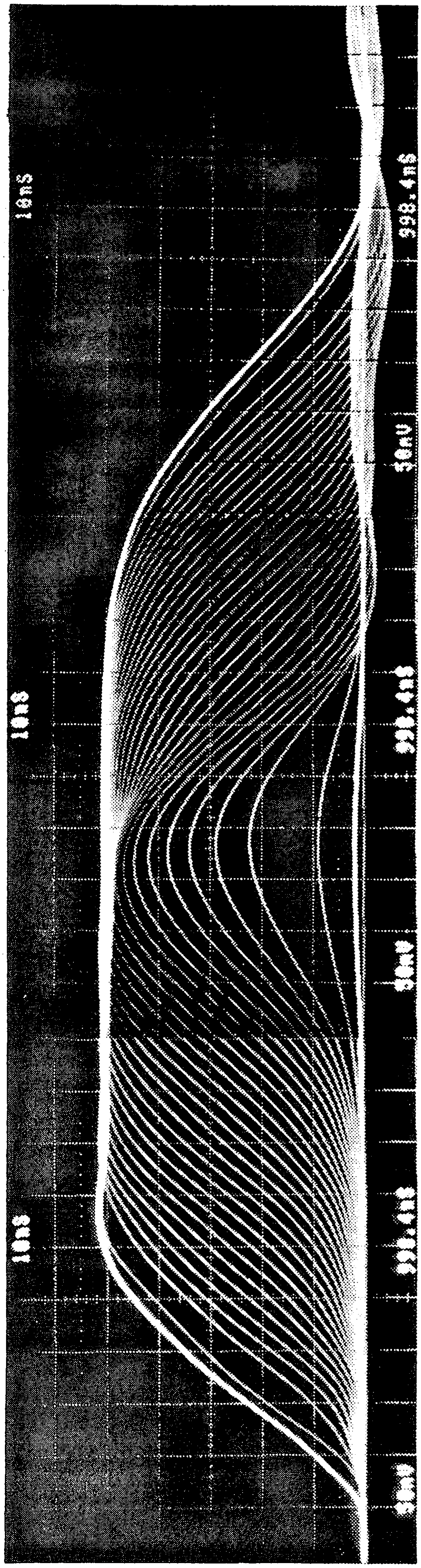


FIG. 9. L.V. Pulse propagation.

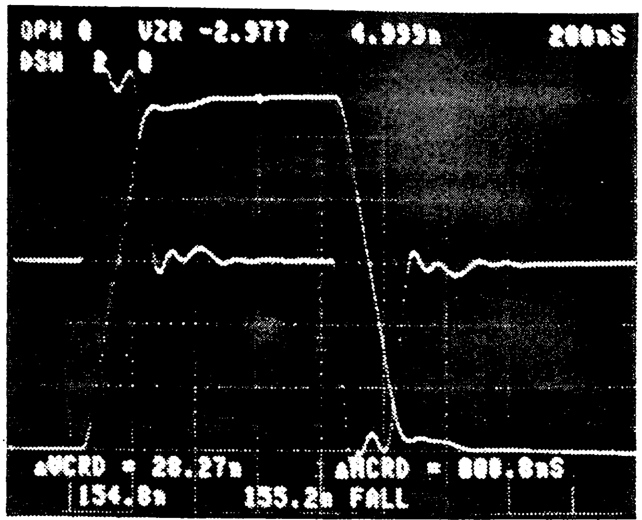


FIG. 10. L.V. $V_1 - V_{21}$ and $\int(V_1 - V_{21})c$

$T_R = 154{,}8$ ns

$T_F = 155{,}2$ ns

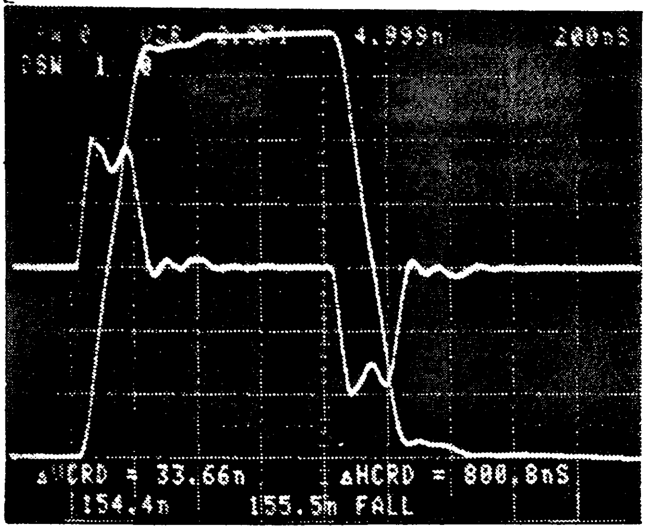


FIG. 11. $\frac{d\phi}{dt}$ and $\int Bdl$ measured with stripline magnetic probe.

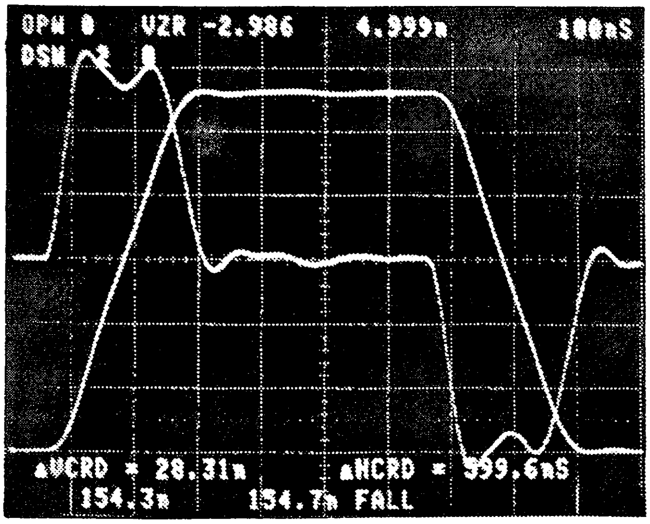


FIG. 12. L.V. $V_1 - V_{21}$ and $\int(V_1 - V_{21})dt$

$C_{IN} = 680$ pF.

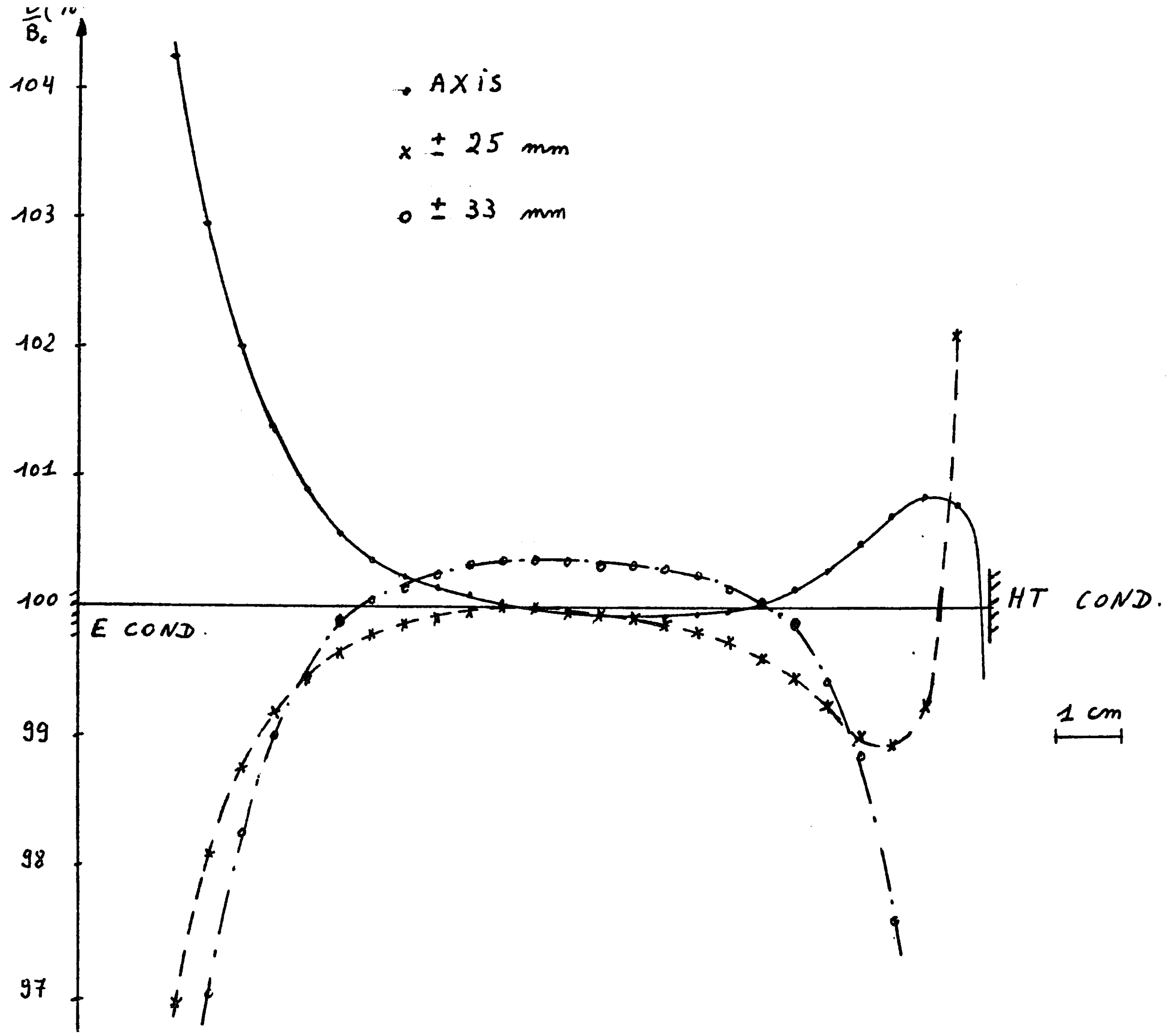


FIG. 13. Field uniformity in aperture.

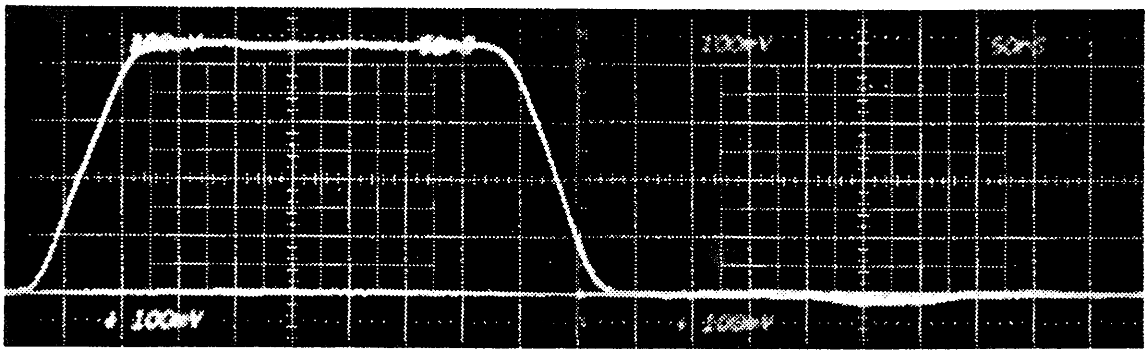


Fig. 14. H.V. 80 kV
$\int$Bdl (C_{IN} = 680 pF)
DS : CX 1671X
reflection : 2,5%

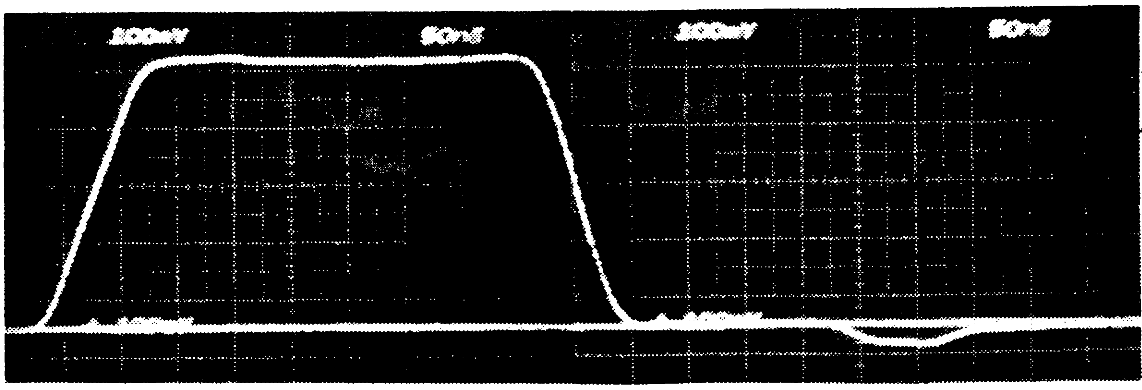


Fig. 15. H.V. 80 kV
$\int$Bdl (C_{IN} = 680 pF)
DS : CX 1671A
reflection : 7%

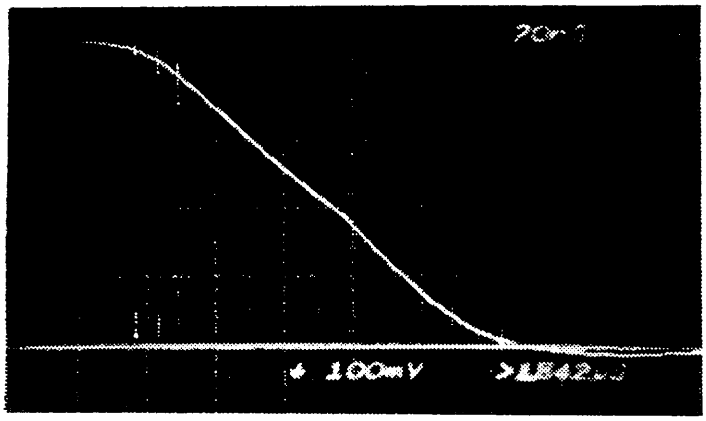


FIG. 16. H.V. 80 kV.

Kick fall 90 – 10% : 160 ns
95 – 5% : 186 ns
98 – 2% : 213 ns

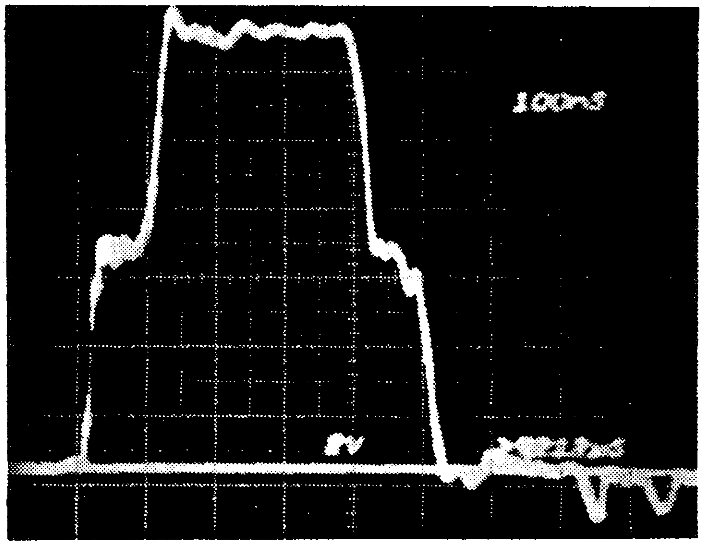


FIG. 17. H.V. 80 kV.
Magnet input current.

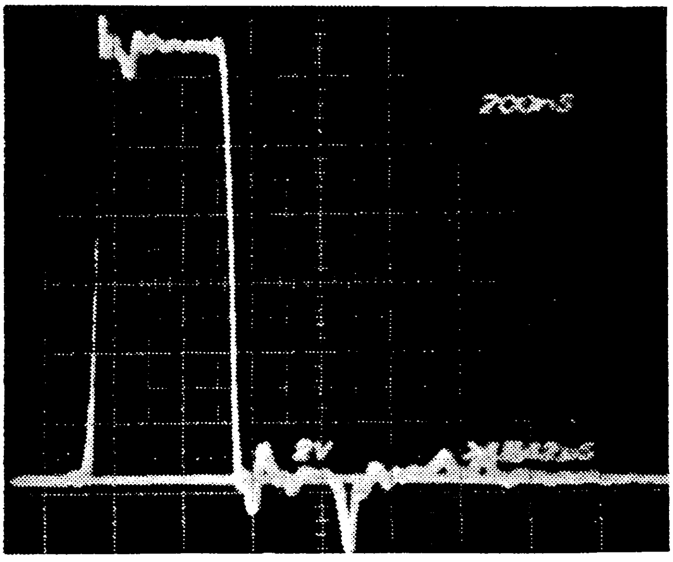
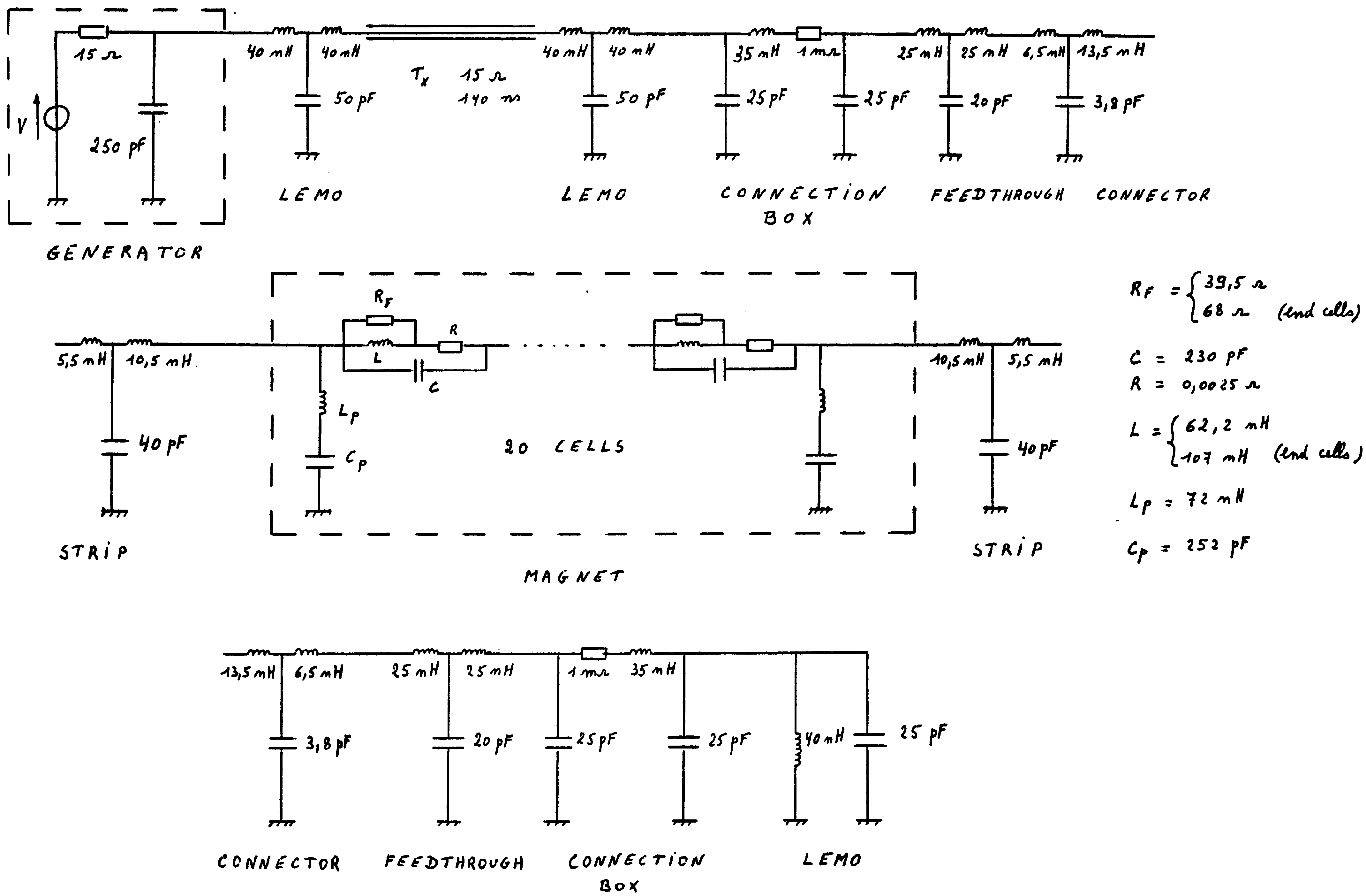


FIG. 18. H.V. 80 kV
Magnet output current.

FIG. 19. Equivalent circuit of magnet K55-3 in the tank.



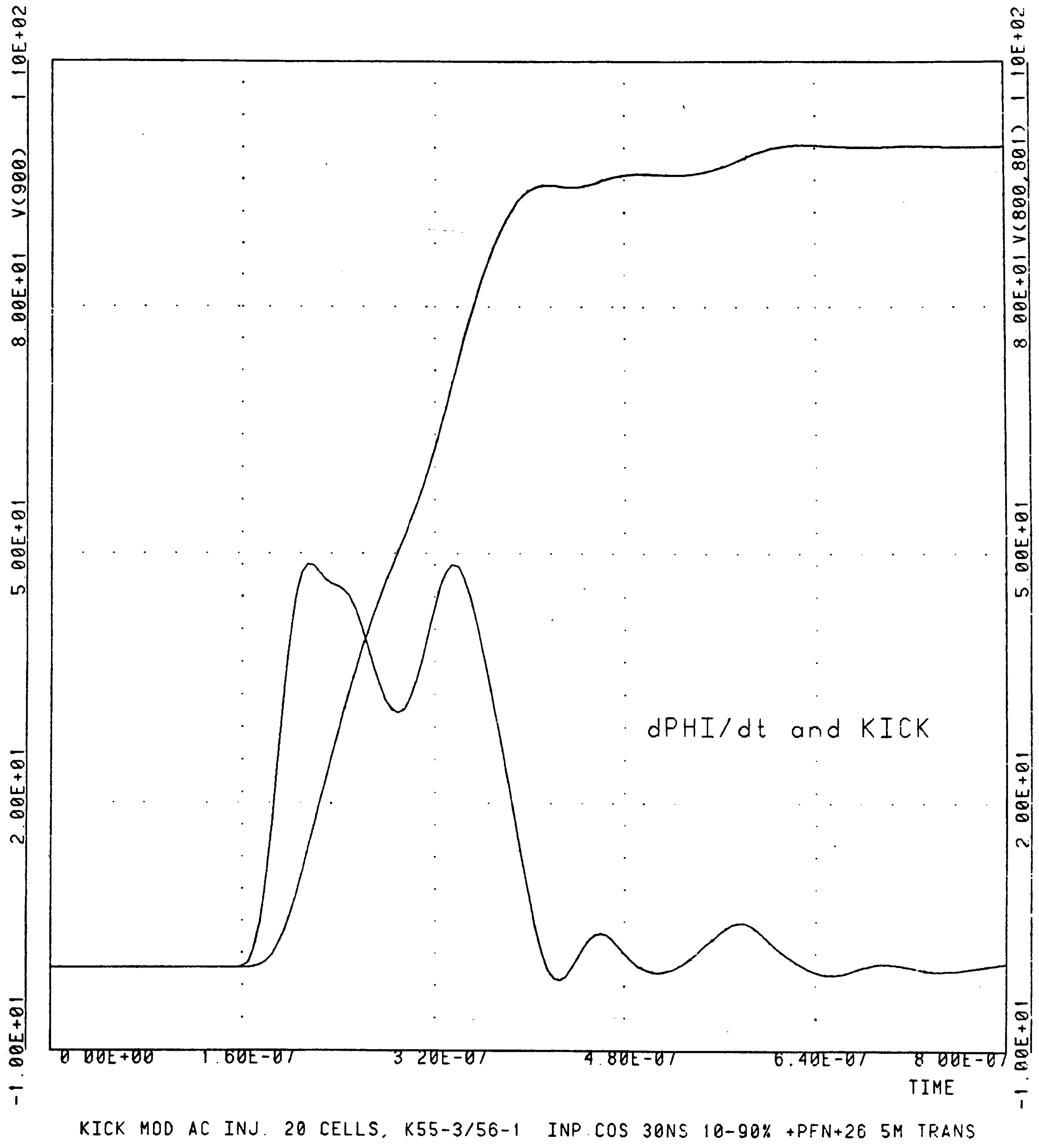


FIG. 20. SPICE results.

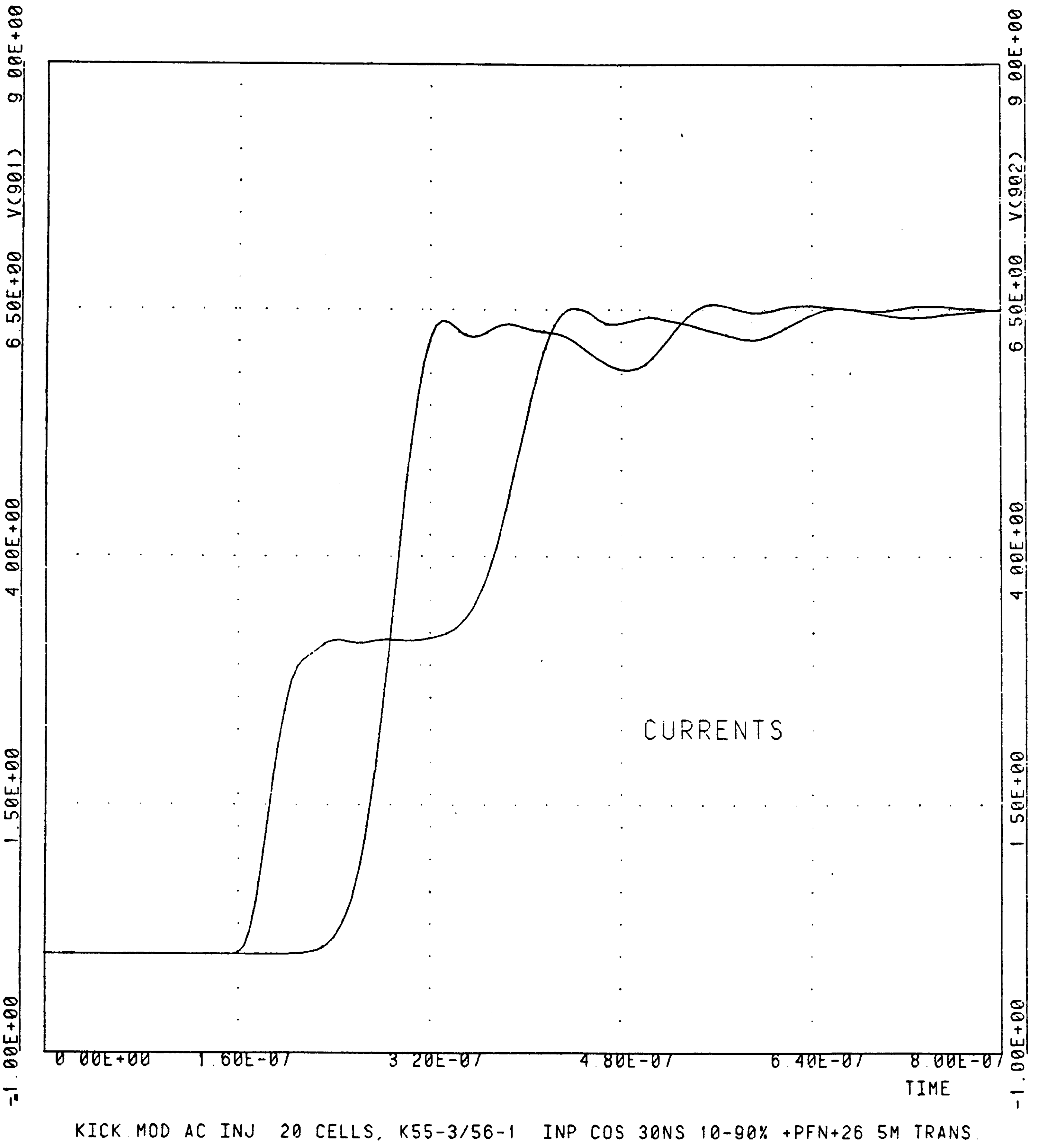


FIG. 21. **SPICE results.**

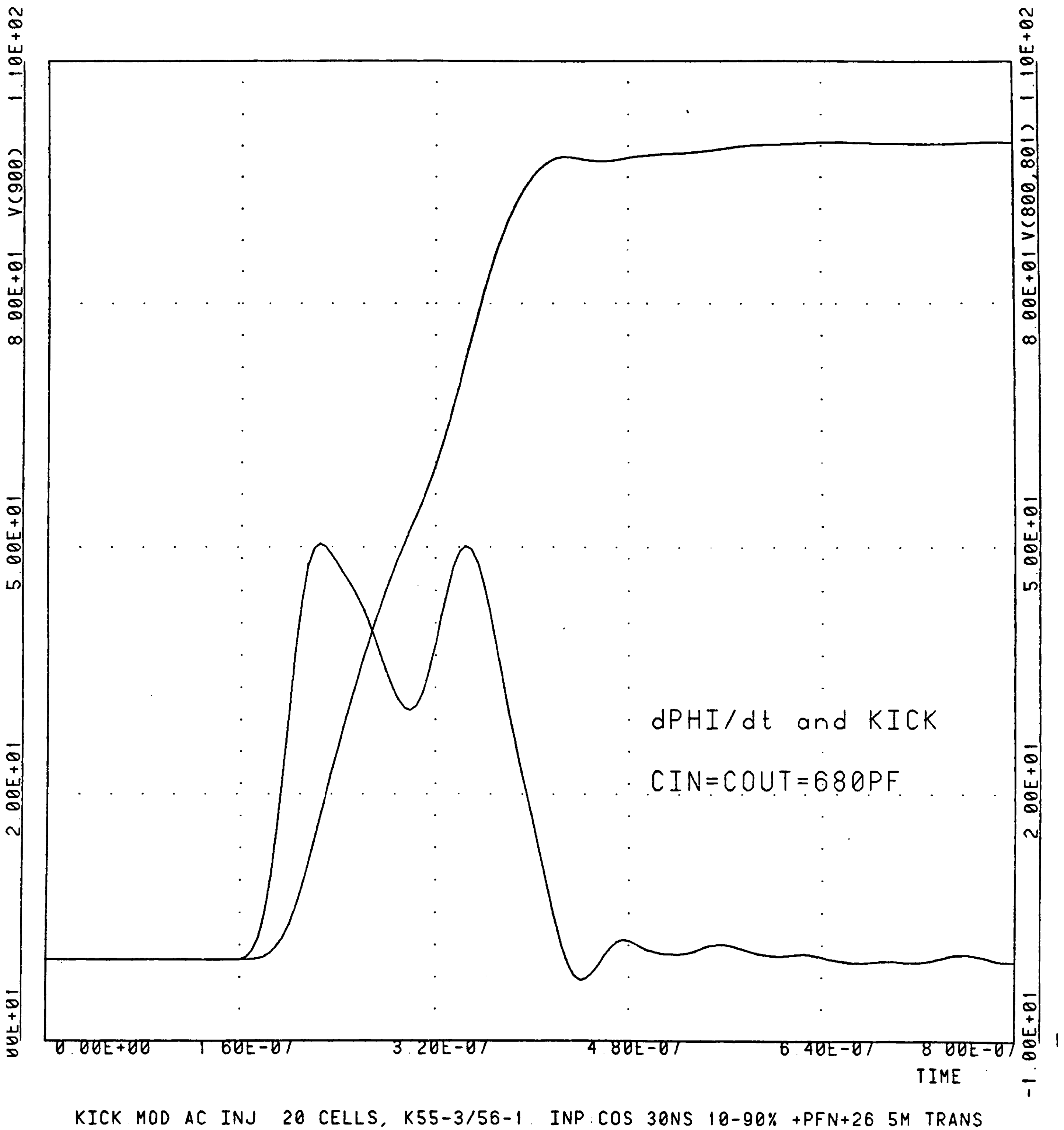


FIG. 22. SPICE results.