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RESULTS OF TESTS ON A ONE-THIRD SCALE MODEL NA-4 MULTIWIRE PROPORTIONAL CHAMBER

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ABSTRACT

This work summarizes some test measurements made with a prototype multiwire proportional chamber (MWPC) for an experiment to extend the inclusive deep inelastic muon scattering on hydrogen to the highest energies (NA-4). Some general requirements for the MWPC are given in other NA-4 communications. The prototype MWPC has a sensitive area of (940 × 400) mm^2, a gap of 7 mm, and a wire spacing of 2 mm. The efficiency of this MWPC on the plateau is 99.9%, and the width of the plateau is more than 800 V. The pulse shape from the sense wire is also investigated.

GENEVA
1976

1. INTRODUCTION

It is proposed to define the trajectory of the scattered muon throughout the iron spectrometer using a total of 40 pairs of proportional planes, each of 3×3 m^2 [1]. All the chambers have a wire spacing of 2 mm and a gap of 7 mm. The wires are grouped in pairs, since high resolution is not required for the experiment. At the maximum value of 10^9 muons/sec each wire has a rate of 10^5 muons/sec. The efficiency of a chamber wire must be more than 99.5% and the dead-time less than 50 nsec [2].

This work reports on measurements made with a 1/3 scale model NA-4 multiwire proportional chamber (MWPC).

2. THE CHAMBER

The construction of the chamber is shown schematically in Fig. 1. Structural rigidity is provided by two sheets of "honeycomb", the inner surfaces of which act as high-voltage planes. The honeycomb material is epoxy-impregnated paper laminated between 0.25 mm sheets of vetronite. Vetronite frames, 25 mm thick and 7 mm deep, locate the printed board carrying the sense wires. A support wire for the sense wires runs down the middle of the chamber, and a spacer to maintain the high-voltage plane separation is placed near the centre of the chamber. Special inserts have been glued into the honeycomb every 100 mm to compress the O-ring and make the chamber gas-tight. The first sense wire (20 microns) is placed 6 mm from the frame. Two thicker wires (50 and 100 microns) are placed at the ends to achieve spatial uniformity in the electric field. High-voltage electrodes have been made of silver paint applied to the honeycomb. Each electrode consists of three strips in the direction of the wires, and each strip is coupled to ground via a capacitor of 1000 pF. The chamber has 192 sense wires which are connected to 6 "Vicking"-type connectors.

3. TRIGGERS AND ELECTRONICS

The chamber could be triggered either by cosmic rays or by 3 MeV electrons from a radioactive source ^{106}Ru ($\sim$ 10 μCi). The cosmic-ray trigger consists of three scintillation counters, each of 8×80 cm^2. The radioactive source trigger includes three small proportional chambers and a scintillation counter. The latter trigger appeared to be very efficient for our tests. Figure 2 shows the profile of particles defined by this trigger.

The electronics which have been used in all measurements with a proportional chamber were described earlier[3]. The read-out electronics have been connected to the proportional chamber via 3 metres of flat cables terminated in 100 Ω.

A diagram of one such channel is shown in Fig. 3. Equivalent input impedance is 100 Ω and the threshold corresponds to 7 μA.

4. RESULTS

The method of our efficiency measurement can be understood by referring to Fig. 2. For each trigger pulse there has to be an event in the region $N_1 - N_2$ (numbers of the wires) of the proportional chamber. This region exceeds the profile of the radioactive source.

4.1 Efficiency, noise, dark current, and timing

Thorough tests of the proportional chamber have been done using different magic gas mixtures. We obtained the efficiency curves shown in Fig. 4. The dark current without the presence of a radioactive source is less than (1-2) μA at the beginning of the plateau, and increases slowly with voltage to (10-16) μA at the end of the plateau. The counting rate due to noise in the chamber is shown in Fig. 4 and is (15-30) events/wire/sec at the end of the plateau. Figure 5 gives the efficiency as a function of the delay between the trigger pulse and strobe for different widths of the strobe pulse.

4.2 Plateau and effect of freon concentrations

In Fig. 4 the efficiency curves are shown for different isobutane concentrations. The beginning of the plateau moves to higher voltages as the isobutane concentration increases. In Fig. 6 the width of plateau curve is shown for these isobutane concentrations. The beginning of the plateau is defined when the efficiency reaches 99.9% and the end of the plateau when the noise reaches (15-30) events/wire/sec. Above this voltage the noise increases very rapidly. It can be seen that the width of the plateau is constant from 25% to 40% isobutane concentration. In Fig. 7 the efficiency curves are shown for three freon concentrations. The maximum width of the plateau without freon is only 300 V. The best results have been obtained with 0.2% freon, 30% isobutane, ∿ 3% methylal, and 67% argon. For this magic gas mixture and 7 μA input threshold the width of the plateau is more than 800 V.

4.3 Total charge and pulse shape

In Fig. 8 we show, as a function of voltage, the total charge curve from the sense wire loaded with c = 600 pF and R = 1 MΩ. The total charge increases approximately tenfold with voltage on the plateau. To investigate the pulse we examine the pictures from the wire loaded with R = 200 Ω. They are given for different voltages and different gas mixtures in Figs. 9-11. Any single avalanche of the pulses can be noticed easily in these pictures. The primary electrons are deposited with equal probability at any distance from the wire[4]. Consequently the output pulse will be a superposition of single avalanches arriving at the wire after various drift times. Big drift times are suppressed by recombination effects of the freon. The width of the pulses increases slowly as the isobutane concentration goes up and the freon concentration goes down. The scale of the current also is shown in these pictures.

4.4 Pulse shape and input impedance of the amplifier

The current pulses from the wire are shown in Figs. 12 and 13 for different input impedances of the amplifier. The wire capacitance is about 20 pF. The current pulse amplitude from the wire as a function of input impedance is shown in Fig. 14.

4.5 Jumper

A small section along one edge of the chamber has been cut out to allow space for the hydrogen target (see Fig. 1). The 64 interrupted sense wires have been connected by a jumper made of teflon-coated flat cable which requires practically no additional space. The efficiency measurements have been done in an orbitrary region of the proportional chamber with and without the jumper. The results are shown in Fig. 15. The pulse shapes with the jumper can be seen in Fig. 16. It can be stated that the flat cable solution for the jumper does not introduce any large distortion in efficiency or in pulse shape.

5. CONCLUSIONS

Using magic gas mixture and simple electronics it is possible to get good efficiency -- 99.9% -- and a good plateau of 800 V. It is necessary to add a small amount of freon. With a low input impedance amplifier, the pulse from the wire is a superposition of many single avalanches. The pulse width is not less than 150 nsec. The current pulse amplitude from the wire can be (200-400) μA at the end of the plateau. The flat cable solution can be used for the jumper to connect the interrupted sense wires.

Acknowledgements

We would like to thank Dr. C. Rubbia for many ideas and useful discussions. We are also grateful to Drs. S. Vorojtsov, D. Schinzel, B. Pishard and F. Nanni and Miss E. Rimmer for many fruitful conversations and help on the testing of the multiwire proportional chamber.

REFERENCES

1) An experiment to extend the inclusive deep inelastic muon scattering on hydrogen and deuterium to the highest energies and four-momentum transfers available at the SPS, CERN/SPSC/74-79/P19, 1 August 1974.

2) C. Rubbia, Status report on the electronics of the multiwire proportional chambers for the SPS experiment P 19, CERN/D.Ph.II/TM-003, 11 March 1975.

3) L. Baksay et al., Multiwire proportional chamber spectrometer for the CERN Intersecting Storage Rings, submitted to Nuclear Instruments and Methods, 16 December 1975.

4) H.G. Fischer, F. Piuz and O. Ullaland, Pulse shape study in a multiwire proportional chamber, CERN/D.Ph.II/DIVERS 75-9, 15 July 1975.

Figure captions

Fig. 1 : Schematic of the prototype multiwire proportional chamber.

Fig. 2 : Profile of the radioactive source ^{106}Ru.

Fig. 3 : Diagram of one channel of the electronics.

Fig. 4 : Efficiency curves and noise counting rate of the multiwire proportional chamber for different isobutane concentrations.

Fig. 5 : Timing curves for coincidence between strobe pulse and trigger pulse.

Fig. 6 : Width of plateau for different isobutane concentrations.

Fig. 7 : Efficiency curves and noise counting rate for different freon concentrations.

Fig. 8 : Total charge as a function of the voltage.

Fig. 9 : Pulse shapes from the wire with 20% isobutane concentration.

Fig. 10 : Pulse shapes from the wire with 30% isobutane concentration.

Fig. 11 : Pulse shapes from the wire with no freon added to the gas mixture.

Fig. 12 : Pulse shapes from the wire with input impedance of R = 0.5 kΩ; 1 kΩ; 1.5 kΩ.

Fig. 13 : Pulse shapes from the wire with input impedance of R = 2 kΩ; 5 kΩ; 10 kΩ.

Fig. 14 : Current pulse amplitude as a function of the input impedance of the amplifier.

Fig. 15 : Efficiency curves with and without the jumper.

Fig. 16 : Pulse shapes from the wire with the jumper.

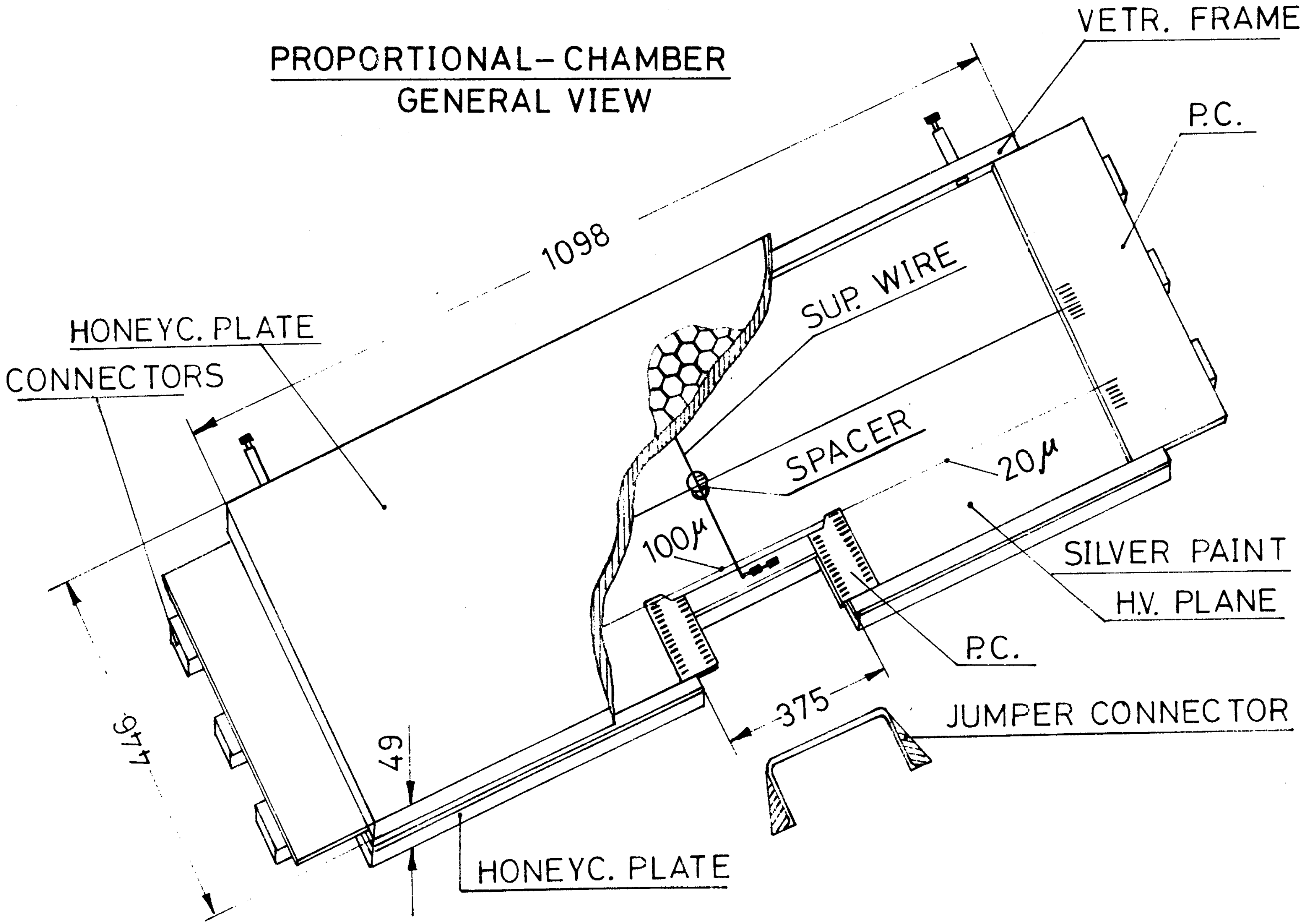
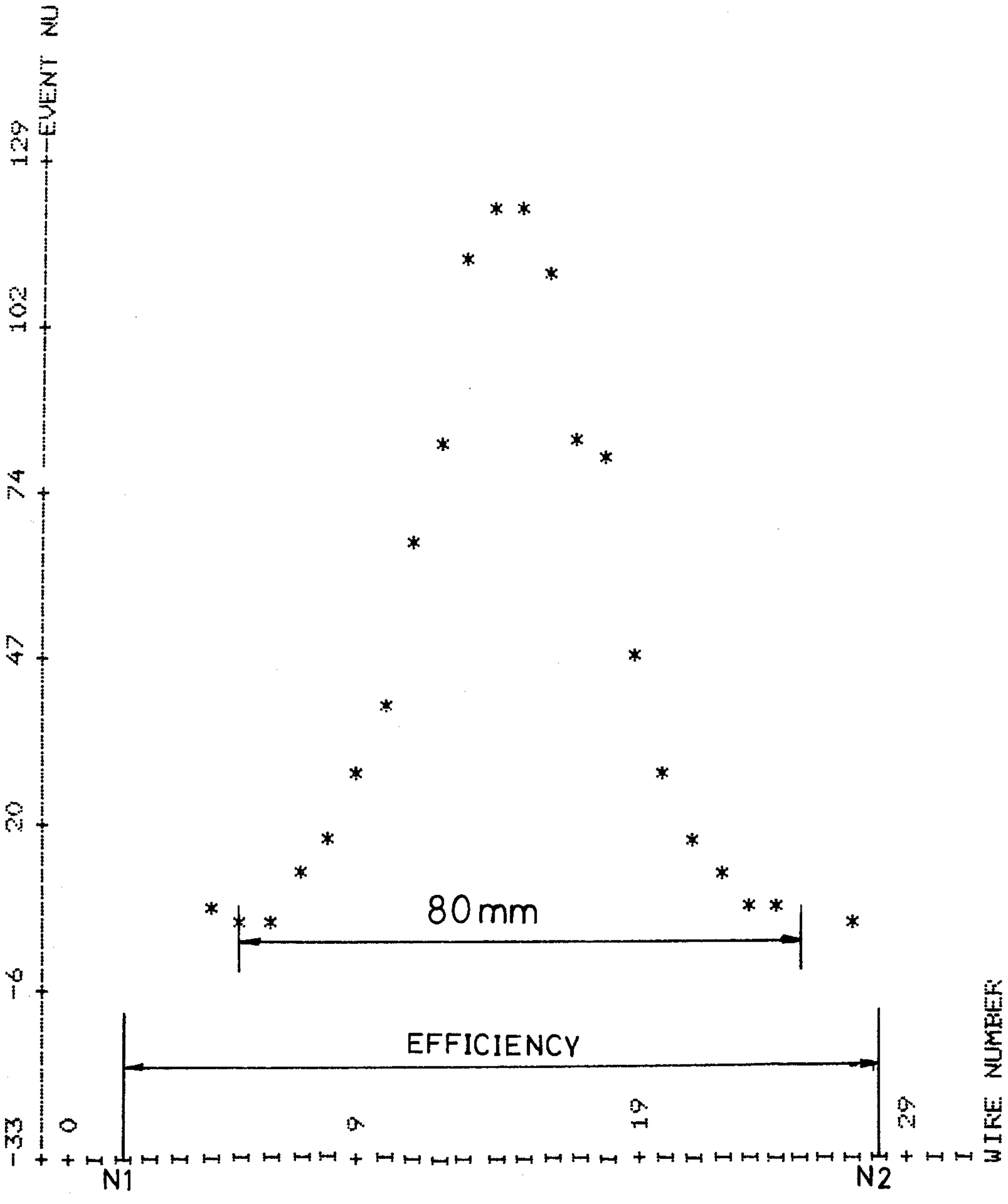
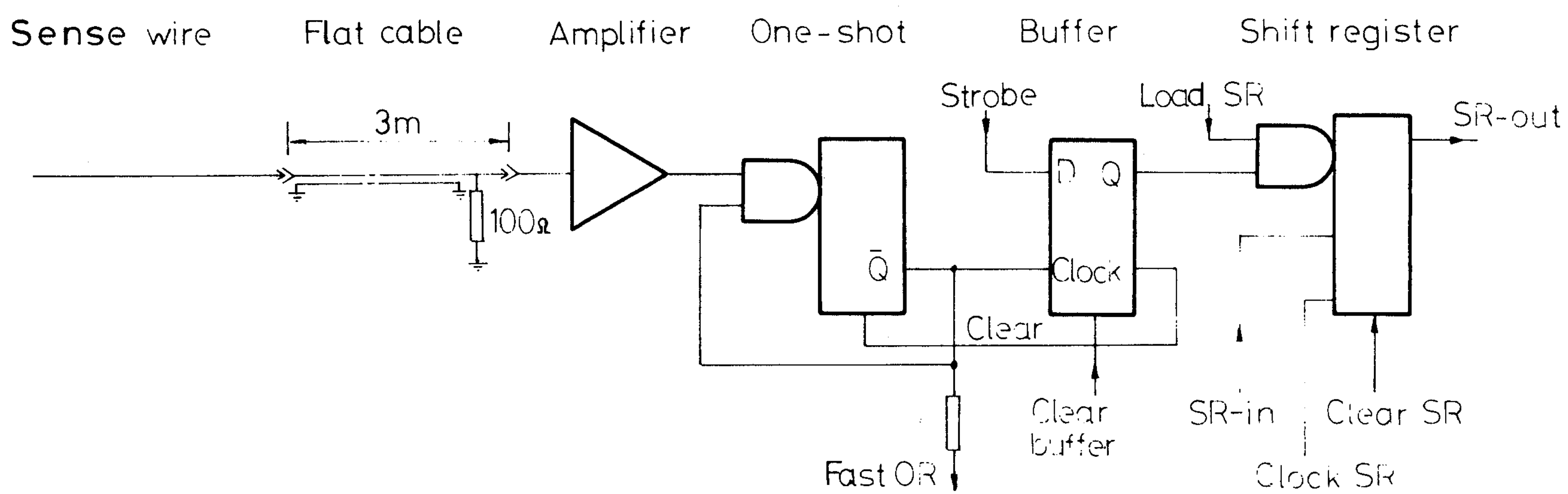

PROPORTIONAL-CHAMBER
GENERAL VIEW
VETR. FRAME
P.C.
1098
SUP. WIRE
HONEYC. PLATE
CONNECTORS
SPACER
20μ
100μ
SILVER PAINT
H.V. PLANE
P.C.
375
JUMPER CONNECTOR
446
49
HONEYC. PLATE

Fig. 1



EVENT NU
129
102
74
47
20
-6
-33
80mm
EFFICIENCY
0
9
19
29
WIRE NUMBER
N1
N2

Fig. 2



Input impedance (with cable type 3380-50 Scotchflex) - 100Ω

Input threshold for test pulse (with cable) ≤ 7 μA

Test pulse

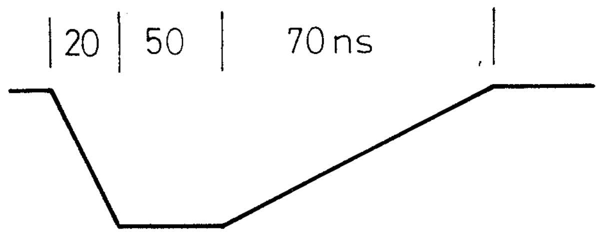


Fig. 3

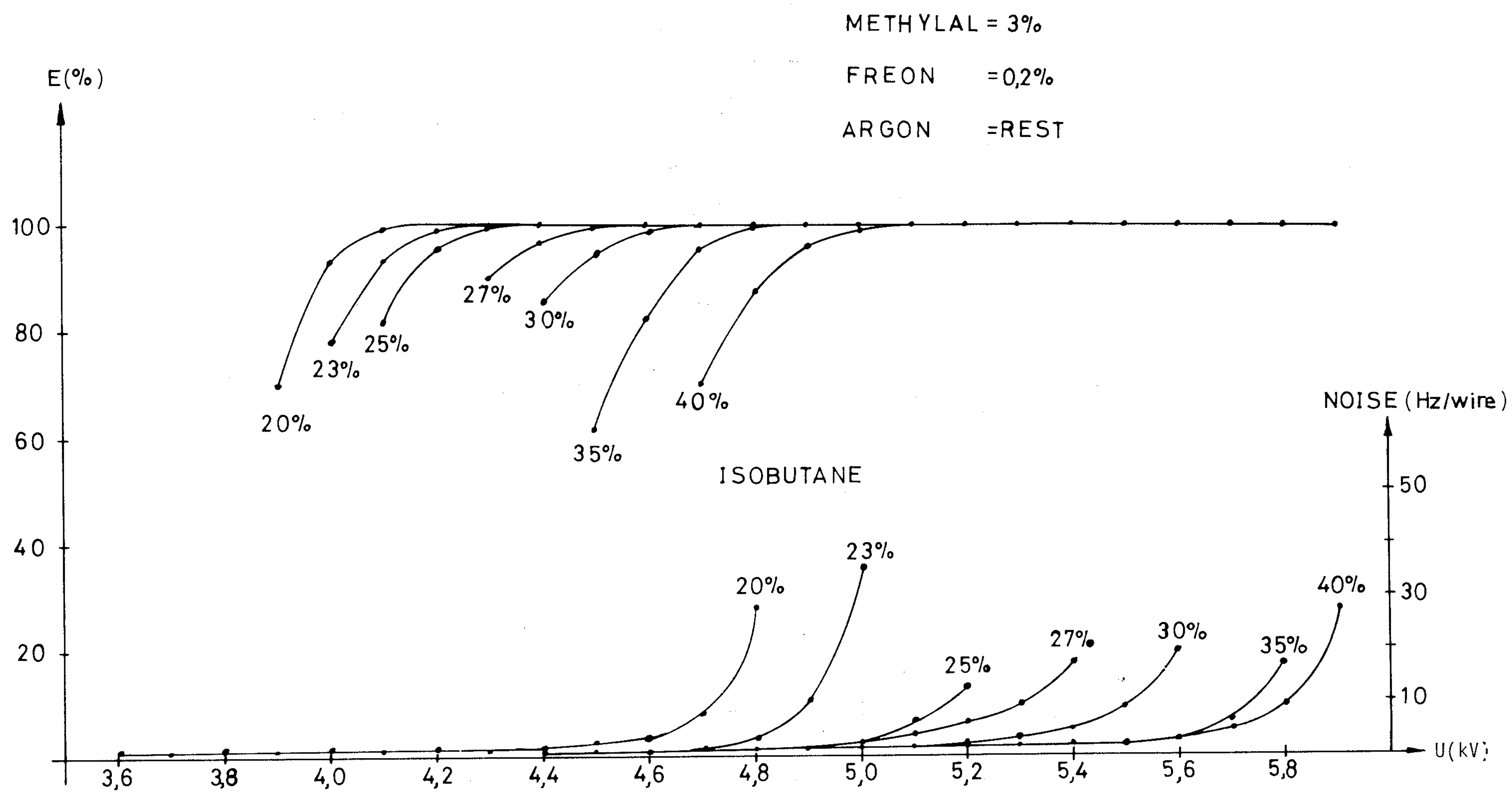
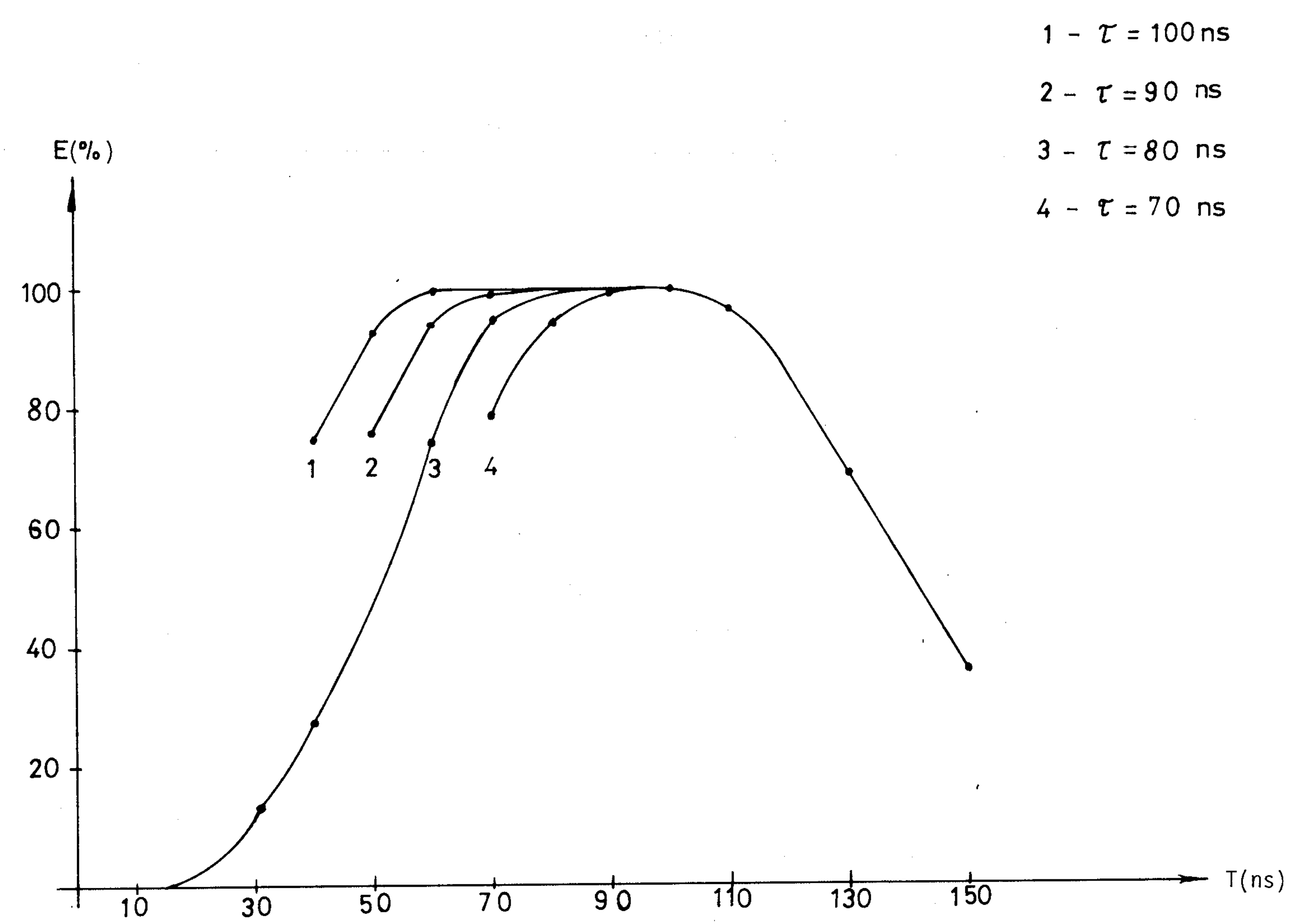

METHYLAL = 3%
FREON =0,2%
ARGON =REST
E(%)
100
80
60
40
20
20%
23%
25%
27%
30%
35%
40%
ISOBUTANE
NOISE (Hz/wire)
50
30
10
U(kV)
3,6
3,8
4,0
4,2
4,4
4,6
4,8
5,0
5,2
5,4
5,6
5,8

Fig. 4



1 - τ = 100 ns
2 - τ = 90 ns
3 - τ = 80 ns
4 - τ = 70 ns
E(%)
100
80
60
40
20
1
2
3
4
10
30
50
70
90
110
130
150
T(ns)

Fig. 5

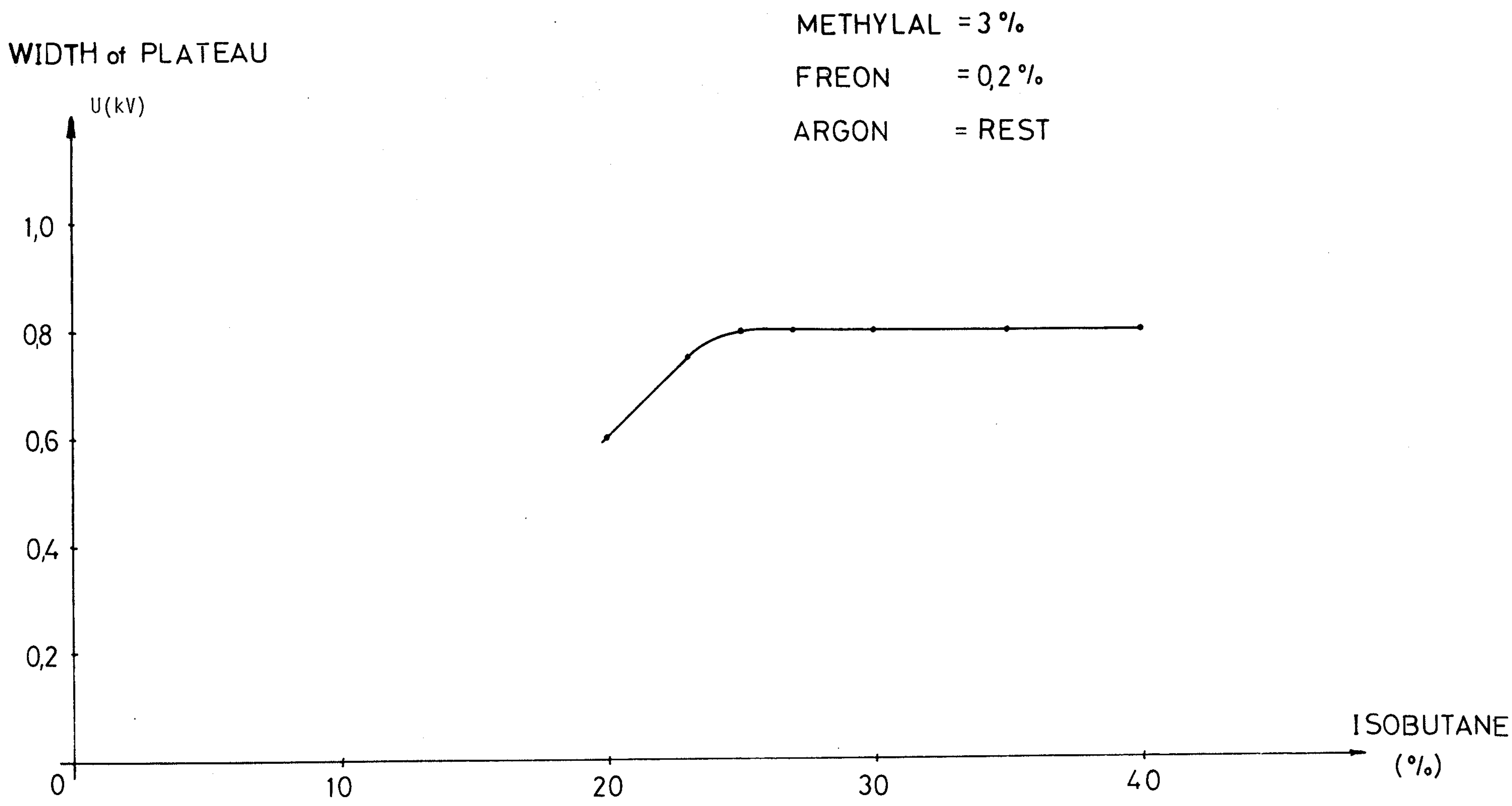

WIDTH of PLATEAU
U(kV)
1,0
0,8
0,6
0,4
0,2
0
10
20
30
40
ISOBUTANE
(%)
METHYLAL = 3 %
FREON = 0,2 %
ARGON = REST

Fig. 6

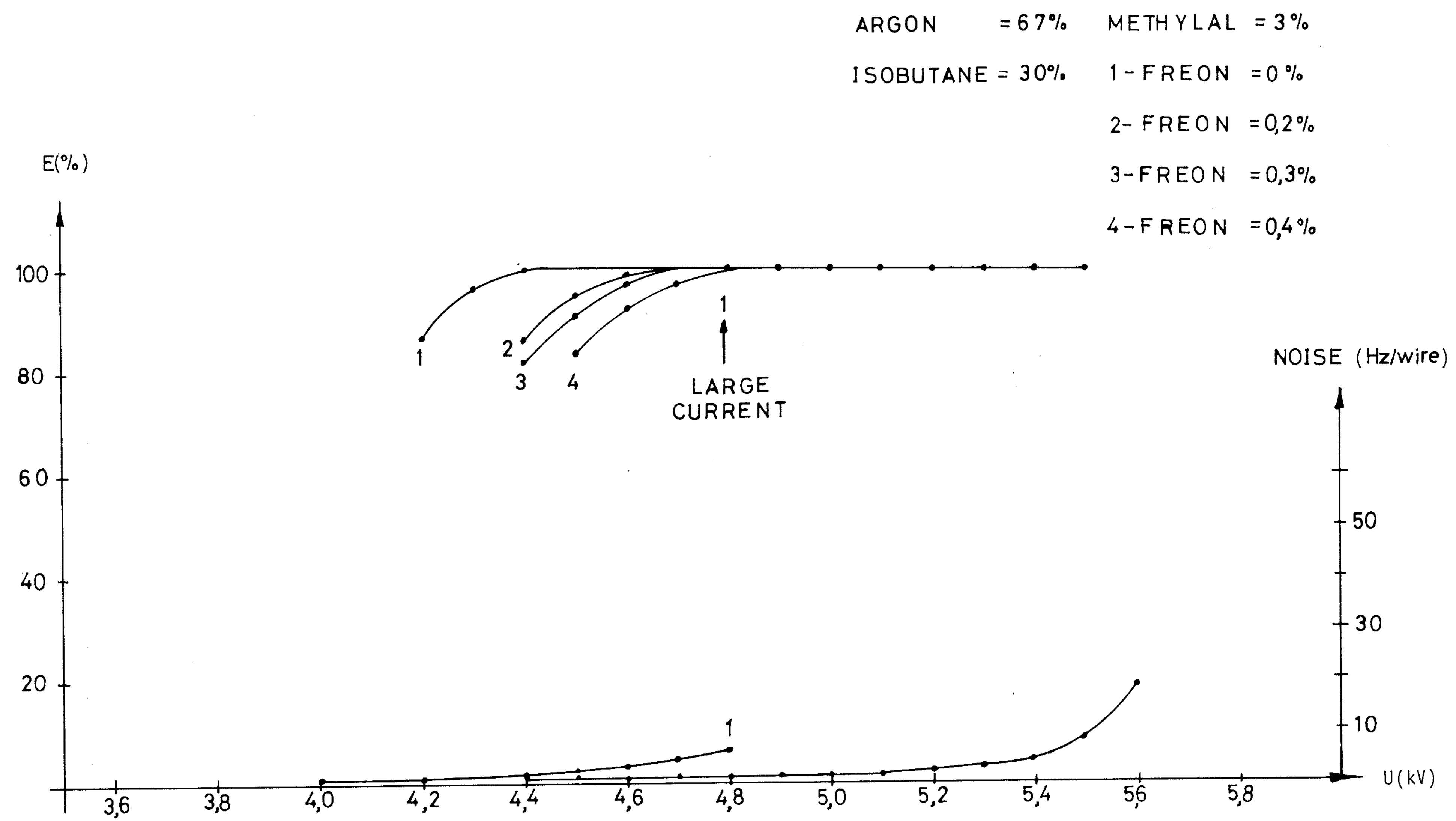

ARGON = 67%
ISOBUTANE = 30%
METHYLAL = 3%
1 - FREON = 0 %
2- FREON = 0,2%
3-FREON = 0,3%
4-FREON = 0,4%
E(%)
100
80
60
40
20
1
2
3
4
1
LARGE
CURRENT
NOISE (Hz/wire)
50
30
10
1
3,6
3,8
4,0
4,2
4,4
4,6
4,8
5,0
5,2
5,4
5,6
5,8
U(kV)

Fig. 7

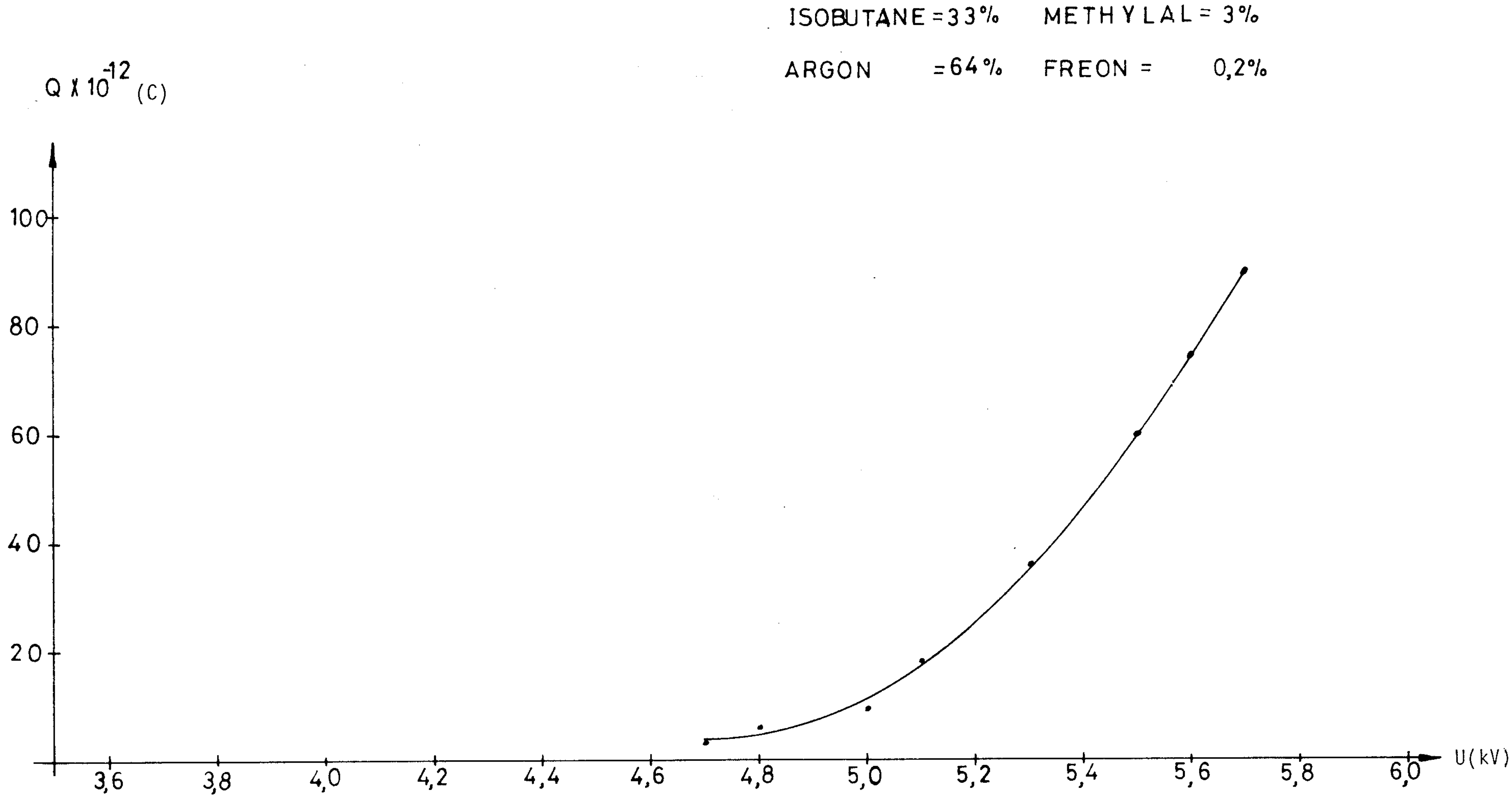
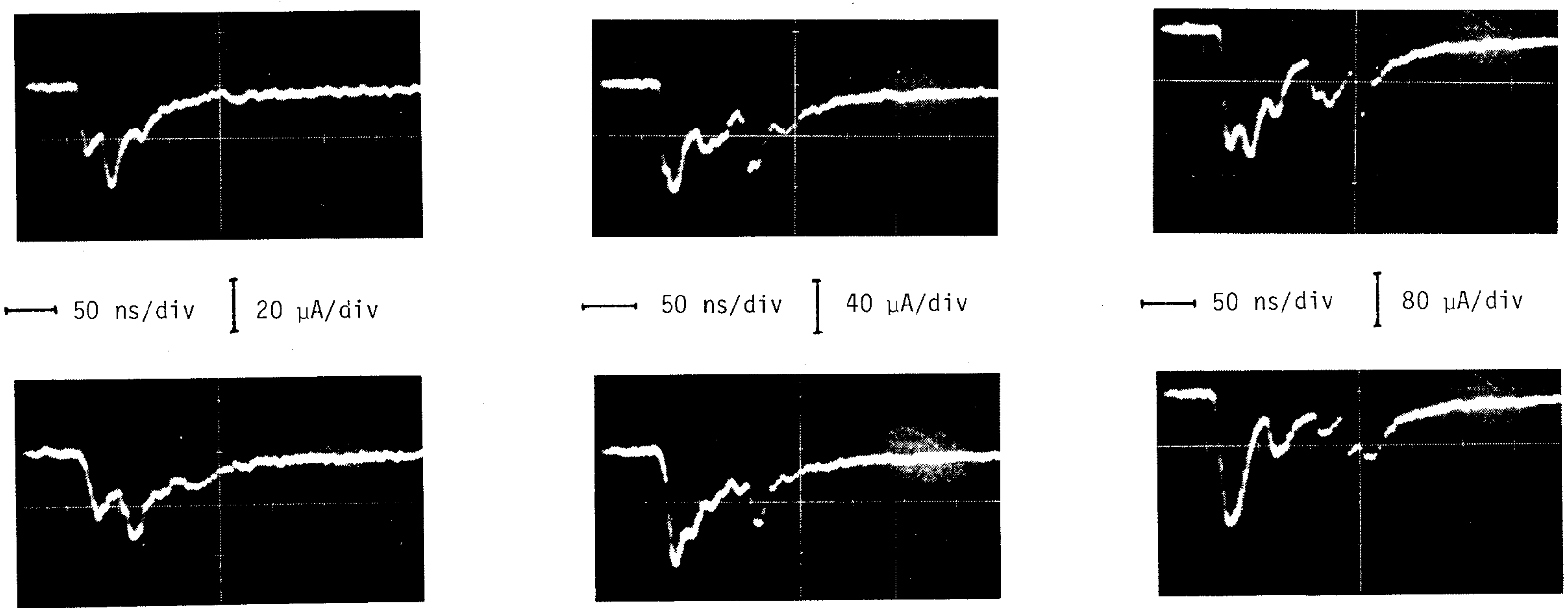

ISOBUTANE = 33%
METHYLAL = 3%
ARGON = 64%
FREON = 0,2%
Q X 10-12 (C)
100
80
60
40
20
3,6
3,8
4,0
4,2
4,4
4,6
4,8
5,0
5,2
5,4
5,6
5,8
6,0
U(kV)

Fig. 8

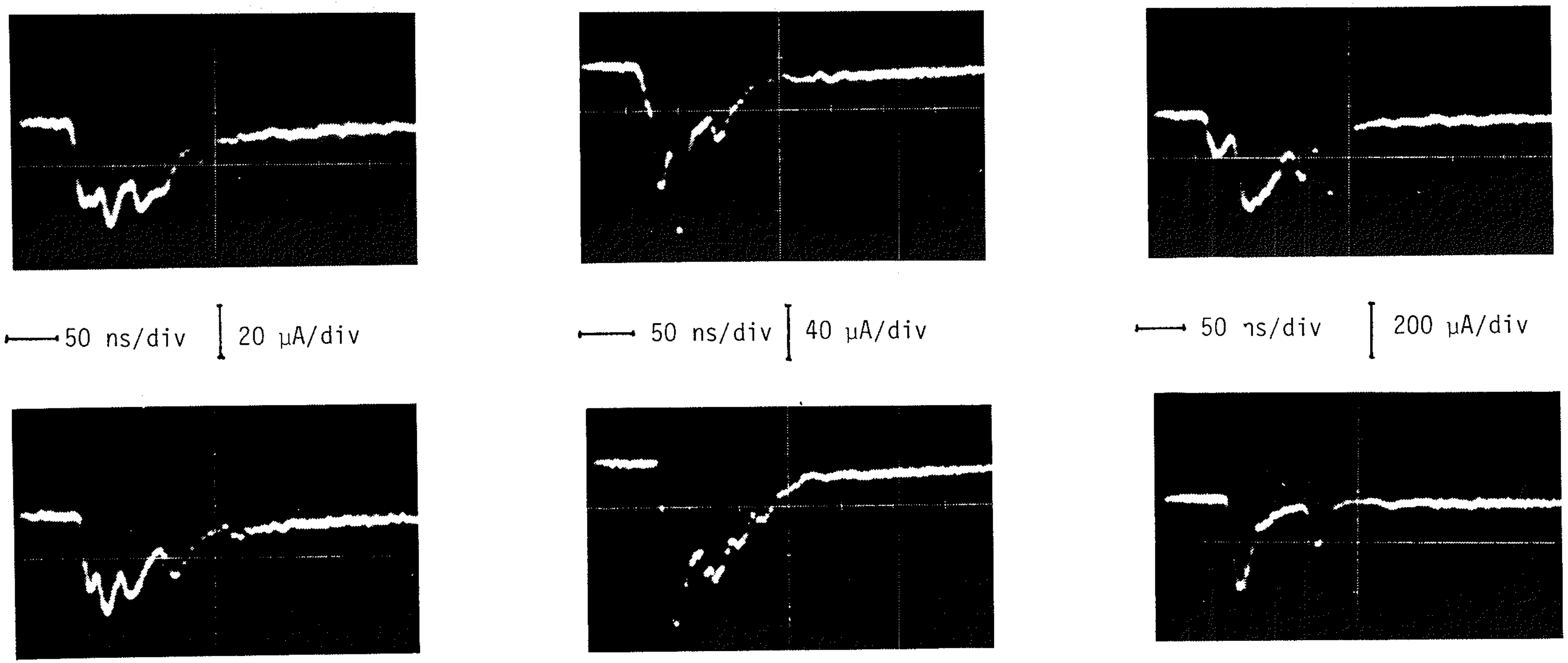
Argon = 77% Methylal = 3% Isobutane = 20% Freon = 0,2%



U = 4,1 kV U = 4,2 kV U = 4,5 kV

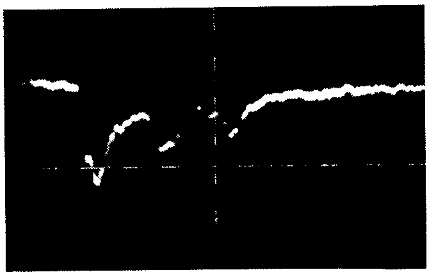
Fig. 9

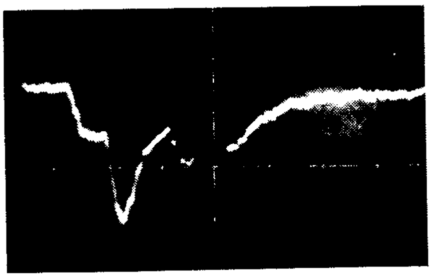
Argon = 67% Methylal = 3% Isobutane = 30% Freon = 0,2%

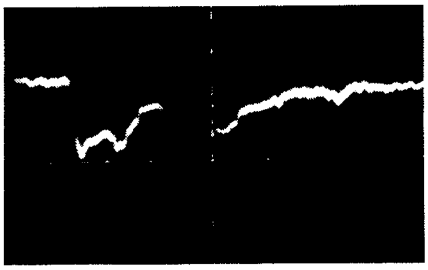


U = 4,8 kV U = 5,0 kV U = 5,3 kV

Fig. 10





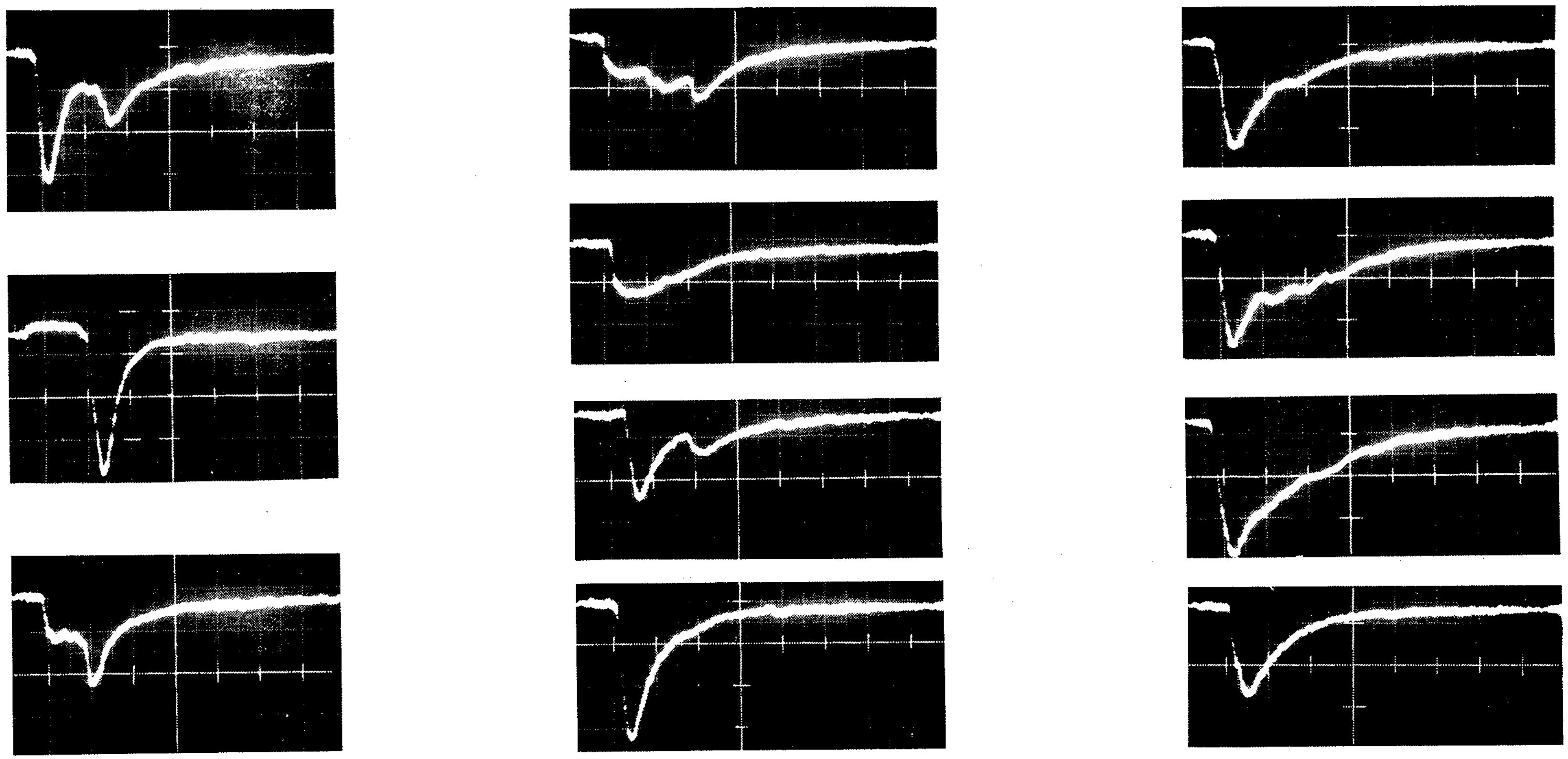


50 ns/div 20 μA/div

U = 4,5 kV
Argon = 67%
Isobutane = 30%
Methylal = 3%

Fig. 11

Argon = 67% Isobutane = 30% Methylal = 3% Freon = 0,2% U = 5 kV

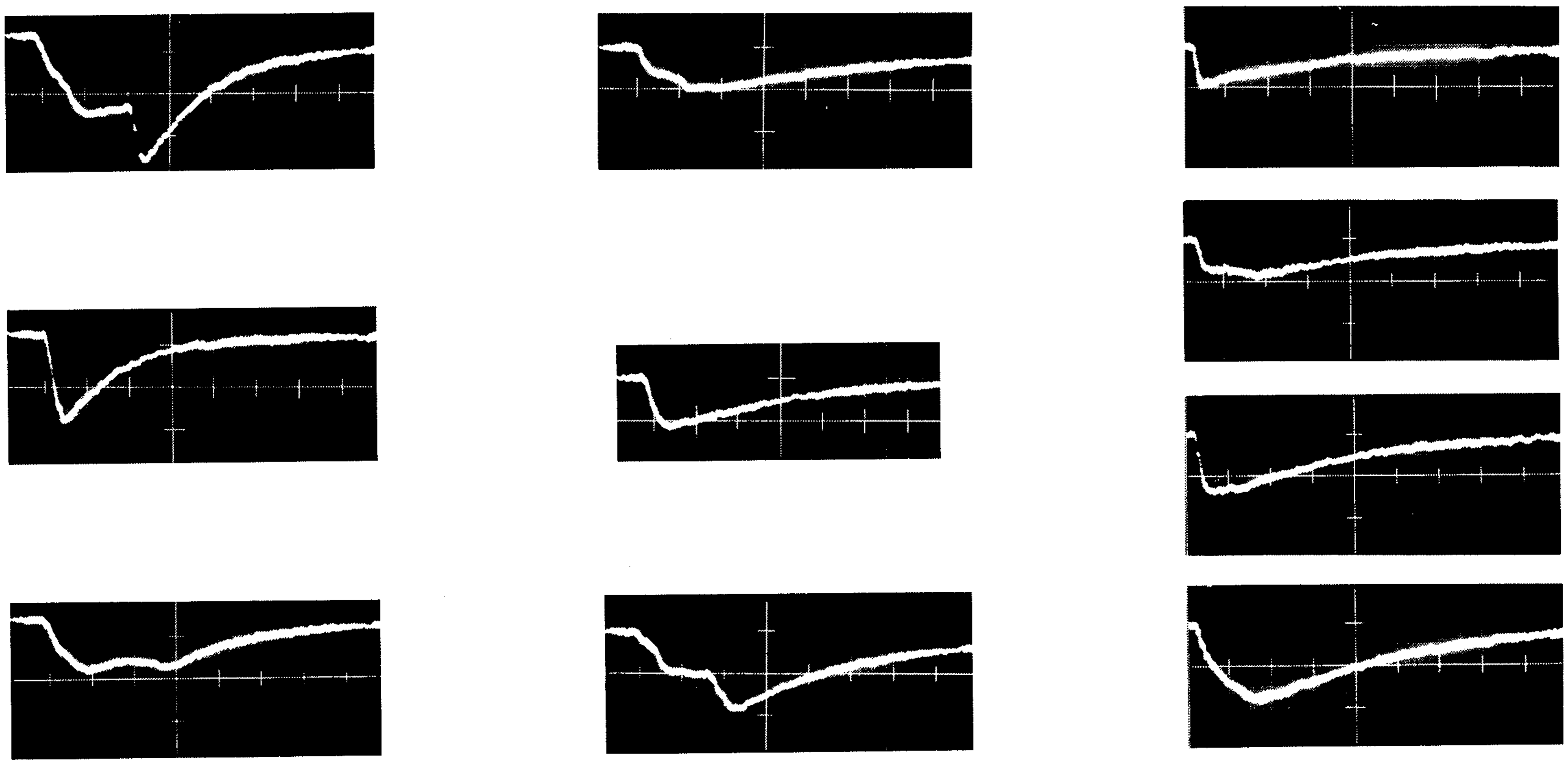


R = 0,5 kΩ R = 1 kΩ R = 1,5 kΩ

50 ns/div 40 μA/div

Fig. 12

Argon = 67%   Isobutane = 30%   Methylal = 3%   Freon = 0,3%   U = 5 kV



R = 2 kΩ   R = 5 kΩ   R = 10 kΩ

50 ns/div   40 μA /div

Fig. 13

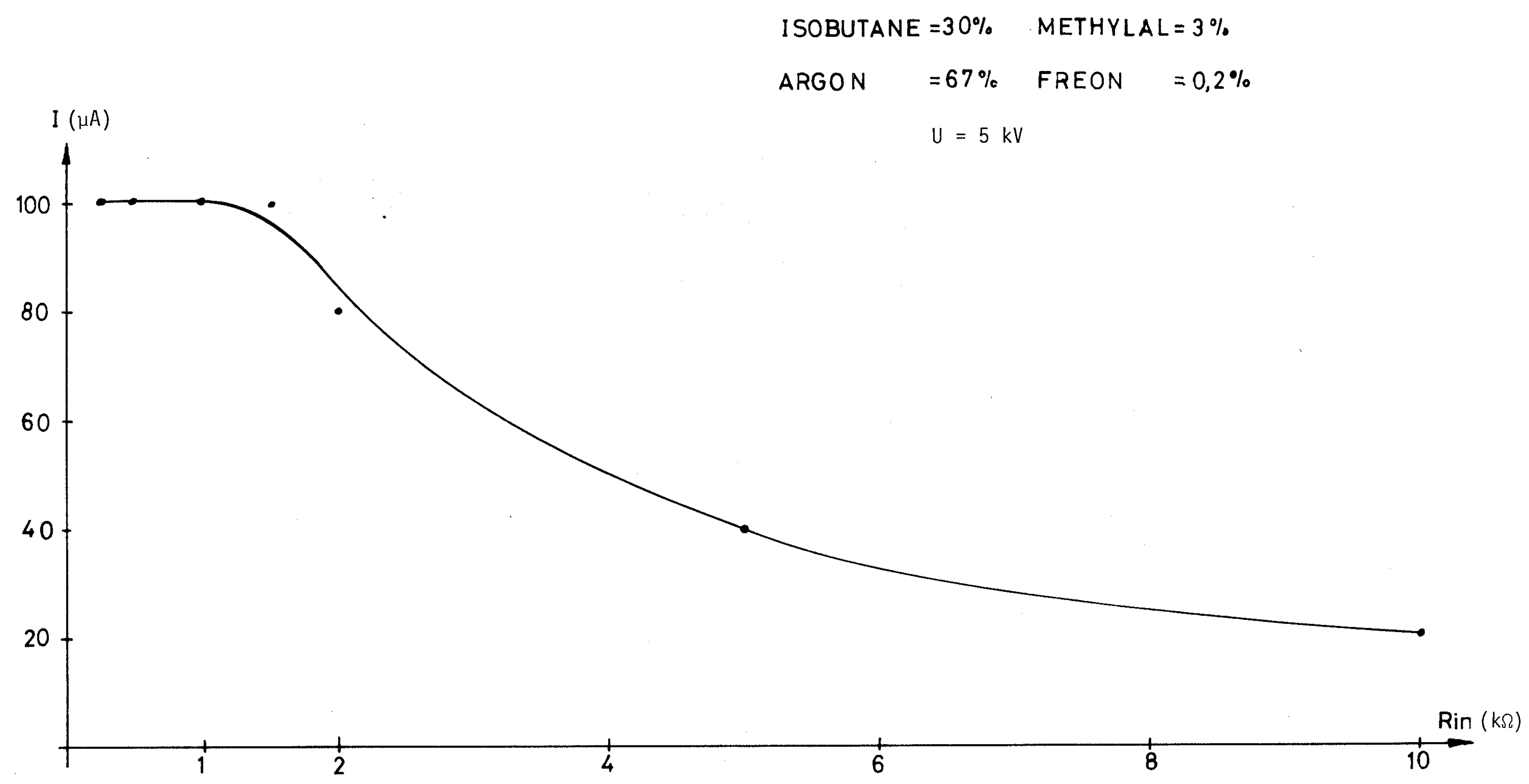

ISOBUTANE =30%
METHYLAL = 3%
ARGON =67%
FREON = 0,2%
U = 5 kV
I (μA)
100
80
60
40
20
Rin (kΩ)
1
2
4
6
8
10

Fig. 14

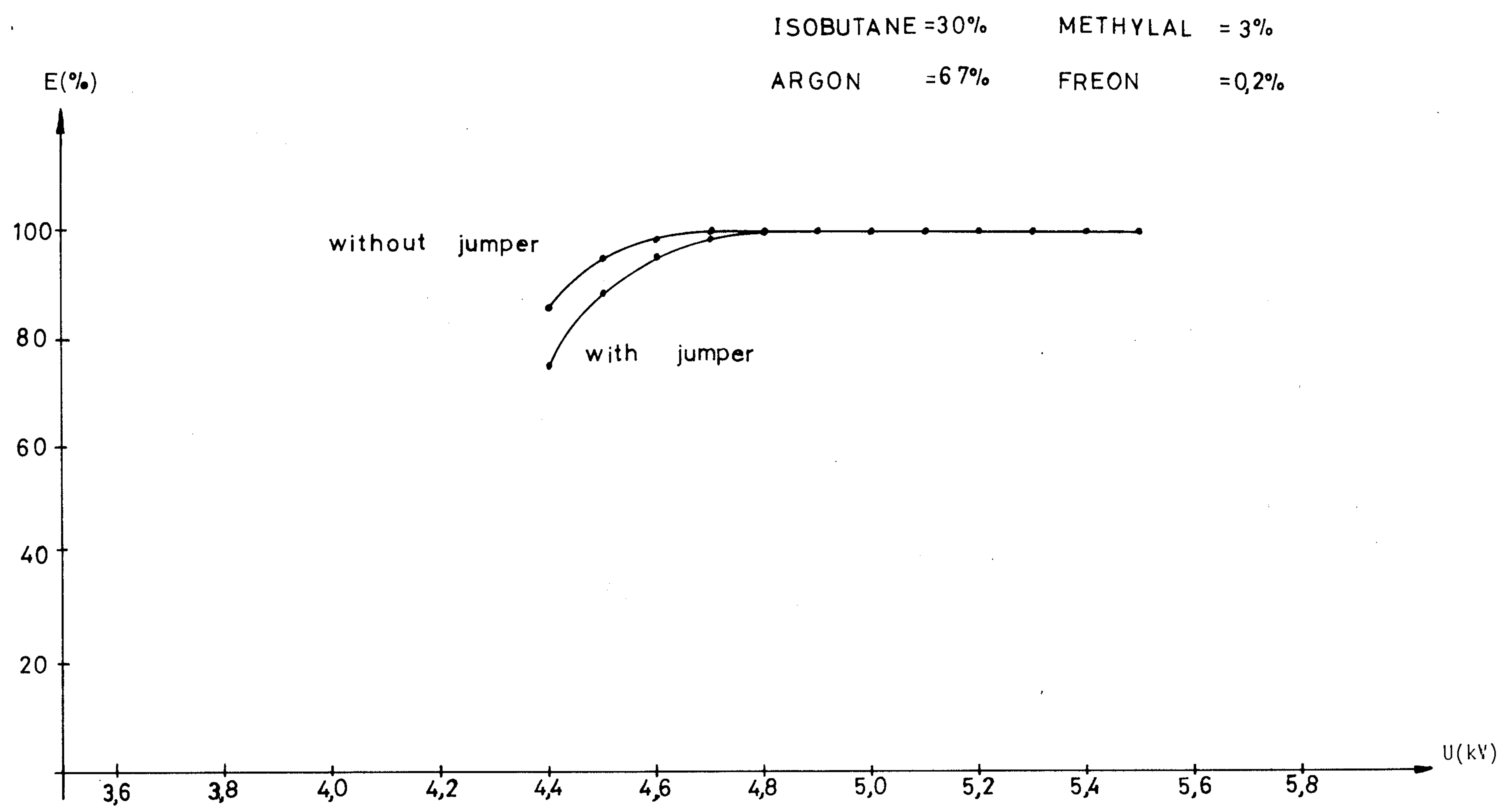
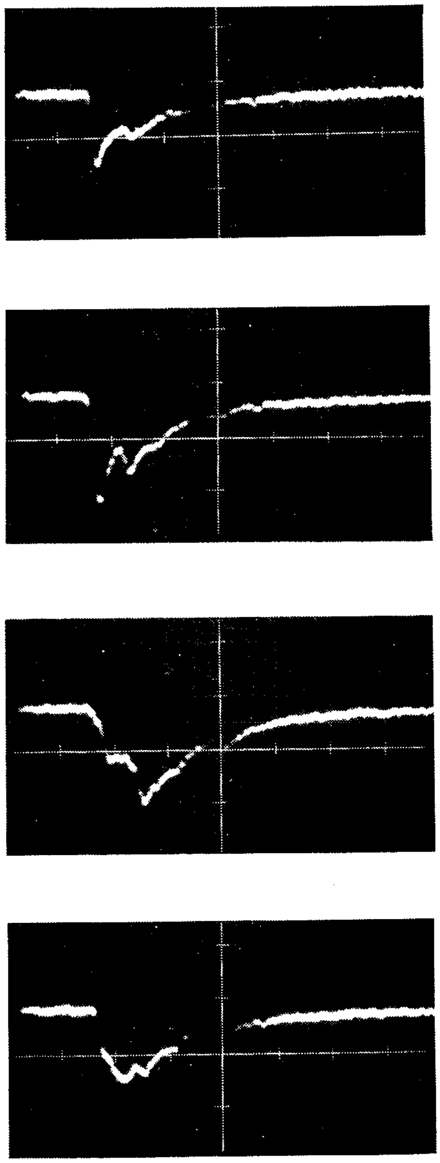

ISOBUTANE =30%
ARGON =67%
METHYLAL = 3%
FREON =0,2%
E(%)
100
80
60
40
20
without jumper
with jumper
U(kV)
3,6
3,8
4,0
4,2
4,4
4,6
4,8
5,0
5,2
5,4
5,6
5,8

Fig. 15



⟼ 50 ns/div | 40 μA/div

U = 5,0 kV (jumper)
Argon = 67%
Isobutane = 30%
Methylal = 3%
Freon = 0,2%

Fig. 16