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OPERATION OF THE PLASTIC STREAMER TUBES OF THE DELPHI HADRON CALORIMETER WITH THE $Ar:CO_2:iso\text{-}C_4H_{10}$ GAS MIXTURE

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This work was performed in the frame of methodic investigations of plastic streamer tubes (PST) for the DELPHI hadron calorimeter[1]. The aim was to find an optimal gas mixture containing ≦ 25-30% of iso-C_4H_{10} and to study the SQS signal sensitivity to variation of mixture component concentrations and gas pressure.

Ar:CO_2:iso-C_4H_{10} (indicated by squares in fig.1) and Ar:iso-C_4H_{10} mixtures with various percentage of components were tested. Argon percentage in the Ar:CO_2:iso-C_4H_{10} mixture is given by

$$\%Ar = 100\% - (\%CO_2 + \%iso\text{-}C_4H_{10}),$$

where $\%CO_2$ and %iso-C_4H_{10} are from the diagram in fig.1.

The gas mixture contains carbon dioxide for safety reasons: a great amount of explosive isobutane in the calorimeter gas volume is undesirable, so the considerable part of isobutane in the "standard" Ar:iso-C_4H_{10}=1:3 mixture was replaced by the inflammable organic gas CO_2[2].

The singles rate n vs the high valtage U and the average streamer charge $\bar{Q}$ vs U curves were obtained for every gas mix-

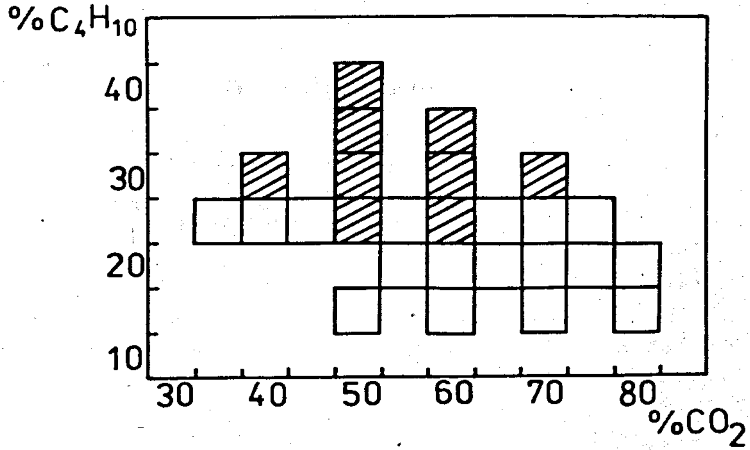


Fig.1. The investigated component concentrations in the Ar:CO_2:iso-C_4H_{10} mixture. Shaded squares depict mixtures, for which the dependence of SQS parameters on pressure was studied.

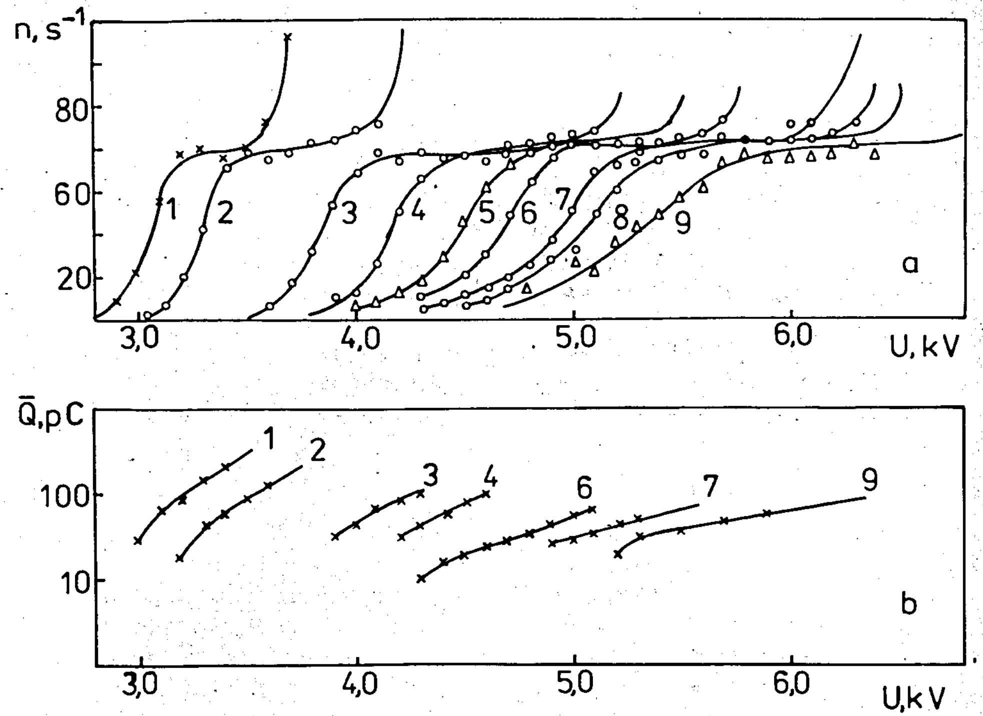


Fig.2. Singles rate (a) and average change (b) characteristics for the Ar:iso-C_4H_{10} mixture with various component concentrations:

1. 60:40.	4. 25:75.	7. 10:90.
2. 50:50.	5. 20:80.	8. 5:95.
3. 35:65.	6. 15:85.	9. 0:100.

ture. The experimental conditions (discrimination threshold 300 μA x 50 Ω, shaping time ≈ 450 ns, anode signal integration time ≈ 300 ns) were uniform through the measurements. The tubes were irradiated by cosmics and β-particles from a ^{90}Sr source.

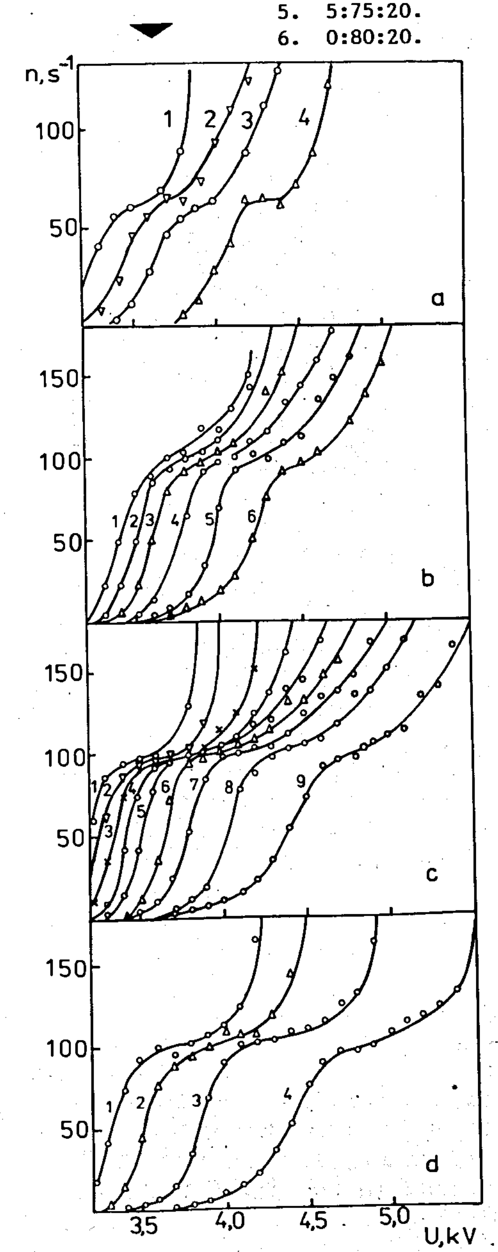
The singles rate and the charge characteristics for Ar:iso-C_4H_{10} mixture are shown in fig.2. Figs.3,4 show the same curves for the Ar:CO_2:iso-C_4H_{10} mixture. These figures allow to conclude the following:

i) an increase in the concentration of iso-C_4H_{10} and, in less degree, of CO_2 leads to a longer singles rate curve plateau and its shifting towards higher voltages.

ii) an increase in the concentration of iso-C_4H_{10} and, in less degree, of CO_2 diminishes the charge curve slope and shifts the curve towards higher voltages.

Fig.3. The singles rate characteristic for the Ar:CO_2:iso-C_4H_{10} mixture with various component concentrations:

a)	b)	c)	d)
1. 35:50:15.	1. 25:50:20.	1. 40:35:25.	1. 30:40:30.
2. 25:60:15.	2. 20:60:20.	2. 35:40:25.	2. 20:50:30.
3. 15:70:15.	3. 15:65:20.	3. 30:45:25.	3. 10:60:30.
4. 5:80:15.	4. 10:70:20.	4. 25:50:25.	4. 0:70:30.
	5. 5:75:20.	5. 20:55:25.	
	6. 0:80:20.	6. 15:60:25.	
		7. 10:65:25.	
		8. 5:70:25.	
		9. 0:75:25.	



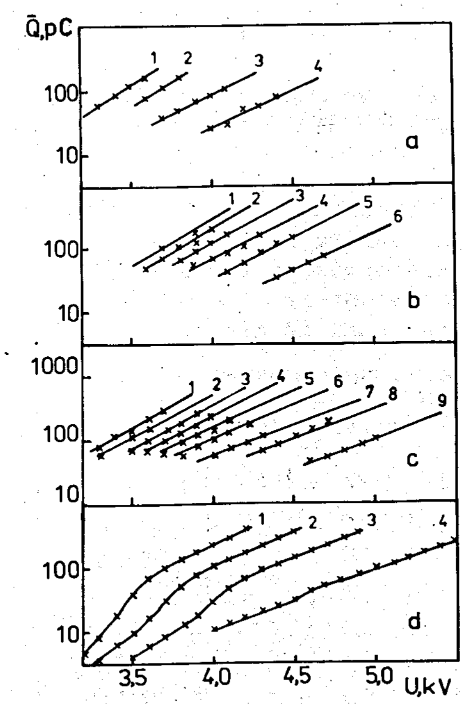


Fig.4. The charge characteristics for the Ar:CO_2:iso-C_4H_{10} mixture with various component concentrations (the numbers indicate the same mixtures as in fig.3).

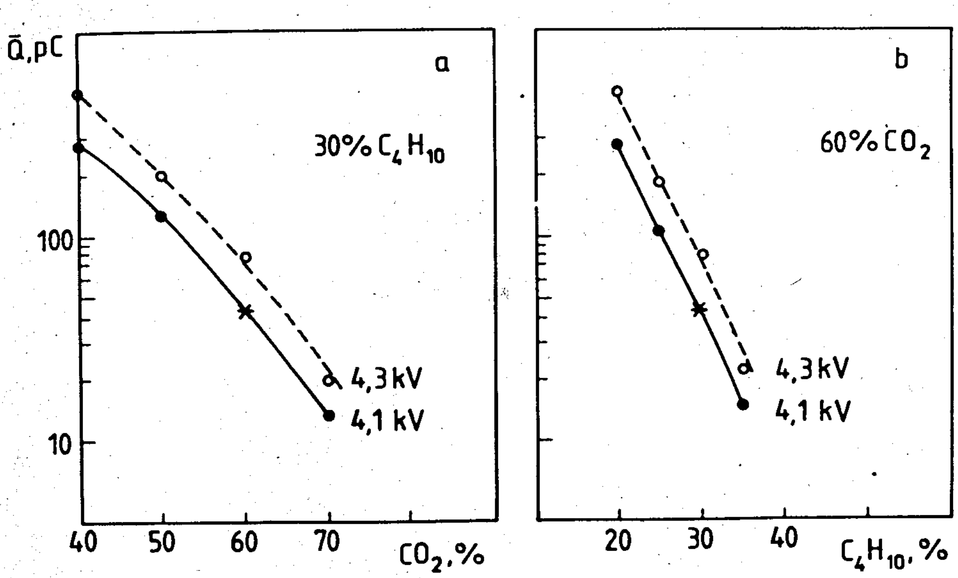


Fig.5. The average streamer charge $\bar{Q}$ vs the component content variation. The asterisk corresponds to the Ar:CO_2:iso-C_4H_{10} = 1:6:3 mixture.

Since the detector properties monotonously improve with increasing iso-C_4H_{10} concentration, a mixture with the maximal permitted content of iso-C_4H_{10} and a relatively small amount of Ar (to lower the operation high voltage U) was chosen, that is Ar:CO_2:iso-C_4H_{10} = 1:6:3.

Table. The plateau shift coefficient k in units V/Torr for the Ar:CO_2 : iso-C_4H_{10} mixtures investigated

Ar : CO_2 : C_4H_{10} =	K, V/torr
=10 : 50 : 40	3.0 ± 0.1
=15 : 50 : 35	2.6 ± 0.1
=20 : 50 : 30	2.3 ± 0.1
=25 : 50 : 30	2.0 ± 0.1
5 : 60 : 35	3.0 ± 0.1
10 : 60 : 30	2.7 ± 0.1
15 : 60 : 25	2.3 ± 0.1
30 : 40 : 30	2.0 ± 0.1
0 : 70 : 30	3.0 ± 0.1
25 : 0 : 75	3.2 ± 0.1

The requirements to the accuracy of gas mixture preparation were also defined. Fig.5 shows $\bar{Q}$ as a function of CO_2 and iso-C_4H_{10} percentage, if the high voltage is constant. This dependence can approximately be considered as exponential:

$$\bar{Q} \approx \bar{Q}_0 \exp(-\gamma_1 C_1 - \gamma_2 C_2),$$

where C_1 and C_2 are the deviations in CO_2 and iso-C_4H_{10} concentration. For the Ar:CO_2: iso-C_4H_{10}=1:6:3 mixture $\gamma_1 \approx$ 0.11 and $\gamma_2 \approx 0.19$, so a 1% increase in the iso-C_4H_{10} con-

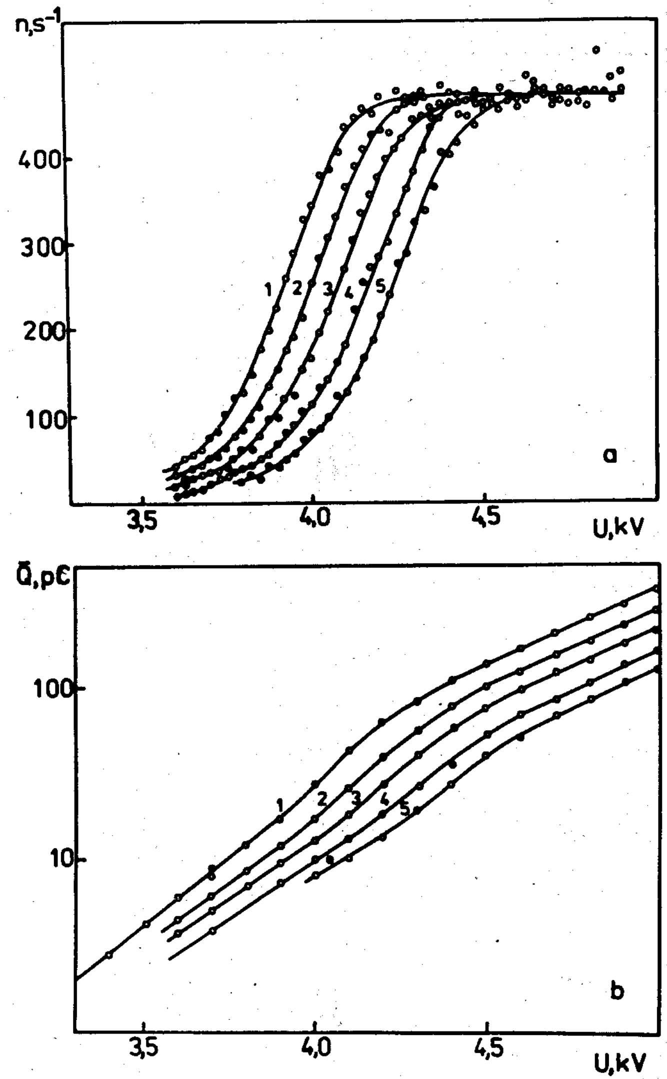


Fig.6. The singles rate (a) and the charge (b) characteristic shift with pressure increase for the Ar:CO_2:iso-C_4H_{10} = 1:6:3 mixture:
1. 766 Torr.
2. 798 Torr.
3. 827 Torr.
4. 864 Torr.
5. 893 Torr.

tent (CO_2 percentage remains constant) decreases $\bar{Q}$ by almost 20%. Hence, if one needs to keep the systematic error of $\bar{Q}$ within $\leq$ 2-3%, it's necessary for the gas system to maintain the mixture component input with $\leq$ 0.1% accuracy.

The results for Ar:CO_2:iso-C_4H_{10} = 1:6:3 mixture exemplify the dependence of the SQS parameters on pressure change.

The singles rate curve shift is shown in fig.6(a). The shift is linear with pressure increase and the corresponding

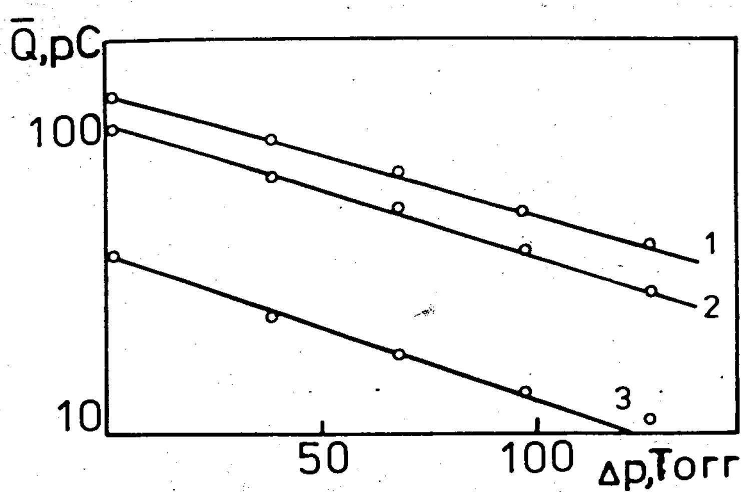


Fig.7. The average streamer charge $\bar{Q}$ vs the pressure change Δp for various values of the high voltage U (Ar:CO_2:iso-C_4H_{10}=1:6:3 mixture). The dependence is approximately exponential:

$\bar{Q} = \bar{Q}_0 \cdot \exp(-\beta \cdot \Delta p)$.

1. U = 4.5 kV; $\beta = 9.0 \cdot 10^{-3}$ $Torr^{-1}$.
2. U = 4.4 kV; $\beta = 9.9 \cdot 10^{-3}$ $Torr^{-1}$.
3. U = 4.1 kV; $\beta = 10.6 \cdot 10^{-3}$ $Torr^{-1}$.

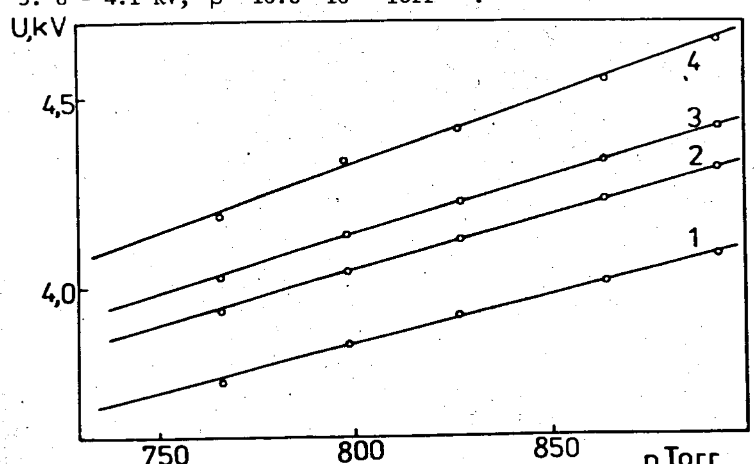


Fig.8. High voltage U vs pressure p for various values of the average streamer charge $\bar{Q}$ (Ar:CO_2:iso-C_4H_{10} = 1:6:3 mixture). The dependence is approximately linear.

1. $\bar{Q}$ = 10 pC; $\alpha = 2.5$ $V \cdot Torr^{-1}$.
2. $\bar{Q}$ = 20 pC; $\alpha = 2.8$ $V \cdot Torr^{-1}$.
3. $\bar{Q}$ = 30 pC; $\alpha = 3.0$ $V \cdot Torr^{-1}$.
4. $\bar{Q}$ = 60 pC; $\alpha = 3.5$ $V \cdot Torr^{-1}$.

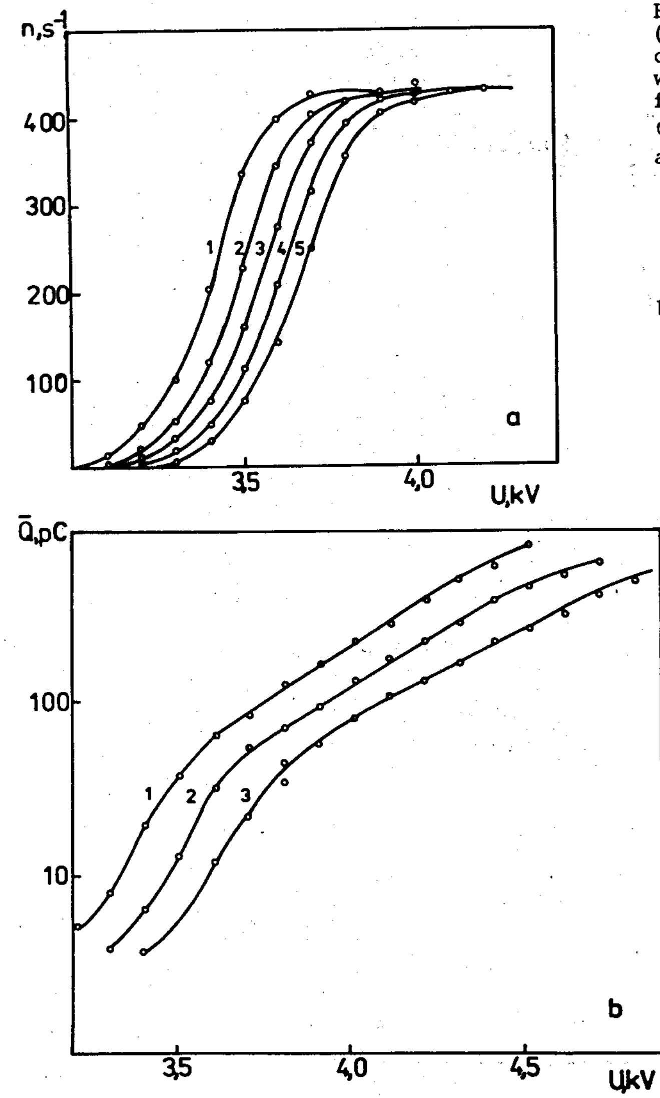


Fig.9. The singles rate (a) and the charge (b) characteristic shift with pressure increase for the Ar:CO_2:iso-C_4H_{10} = 25:50:25

a) 1. p = 765 Torr.
   2. p = 804 Torr.
   3. p = 834 Torr.
   4. p = 863 Torr.
   5. p = 892 Torr.

b) 1. p = 763 Torr.
   2. p = 824 Torr.
   3. p = 882 Torr.

proportionality coefficient k (plateau shift coefficient) is presented in the Table for the chosen mixture and for all mixtures investigated.

The charge characteristics modification is shown in fig.6(b). The average streamer charge $\bar{Q}$ is plotted in Fig.7 vs pressure change Δp at constant high voltage. The dependence is exponential in a wide range of pressures:

$\bar{Q} \approx \bar{Q}_0 \cdot \exp(-\beta \cdot \Delta p)$.

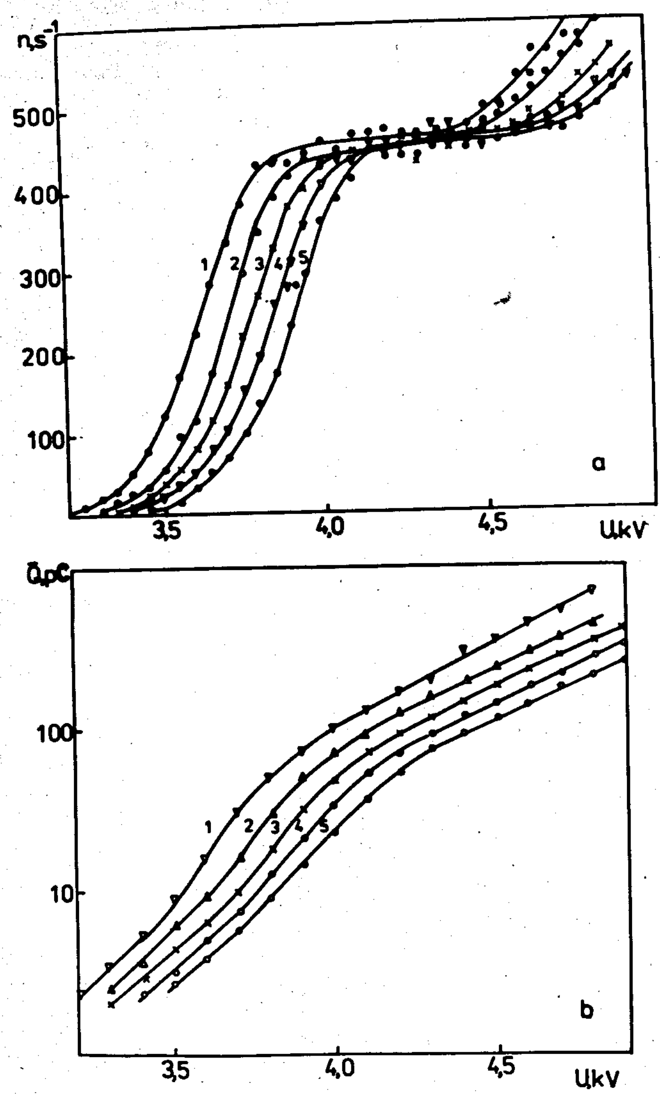


Fig.10. The singles rate (a) and the charge (b) charateristic shift with pressure increase for the $Ar:CO_2$: iso-C_2H_{10}=20:50:30 mixture:

1. p = 765 Torr.
2. p = 804 Torr.
3. p = 834 Torr.
4. p = 863 Torr.
5. p = 892 Torr.

Fig.8 shows, how it is necessary to tune the high voltage to maintain the chosen average charge constant when the pressure changes. The dependence is approximately linear.

Figs.9-17 illustrate the singles rate and charge characteristics shift with the pressure increase for all mixtures investigated.

The β (charge sensitivity to pressure change at U = const) vs U and α (the coefficient "feedback" necessary to maintain $\bar{Q}$ = const) vs $\bar{Q}$ curves are shown in figs.18,19.

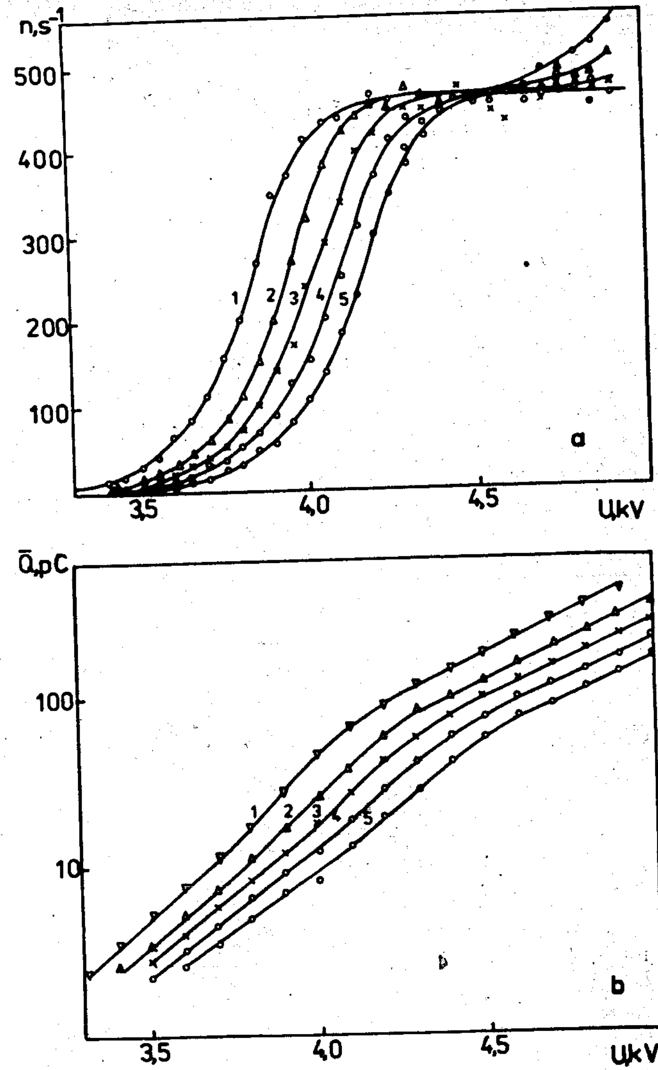


Fig.11. The singles rate (a) and the charge (b) characteristic shift with pressure increase for the $Ar:CO_2$: iso-C_4H_{10}=15:50:35 mixture:

1. p = 764 Torr.
2. p = 803 Torr.
3. p = 836 Torr.
4. p = 865 Torr.
5. p = 895 Torr.

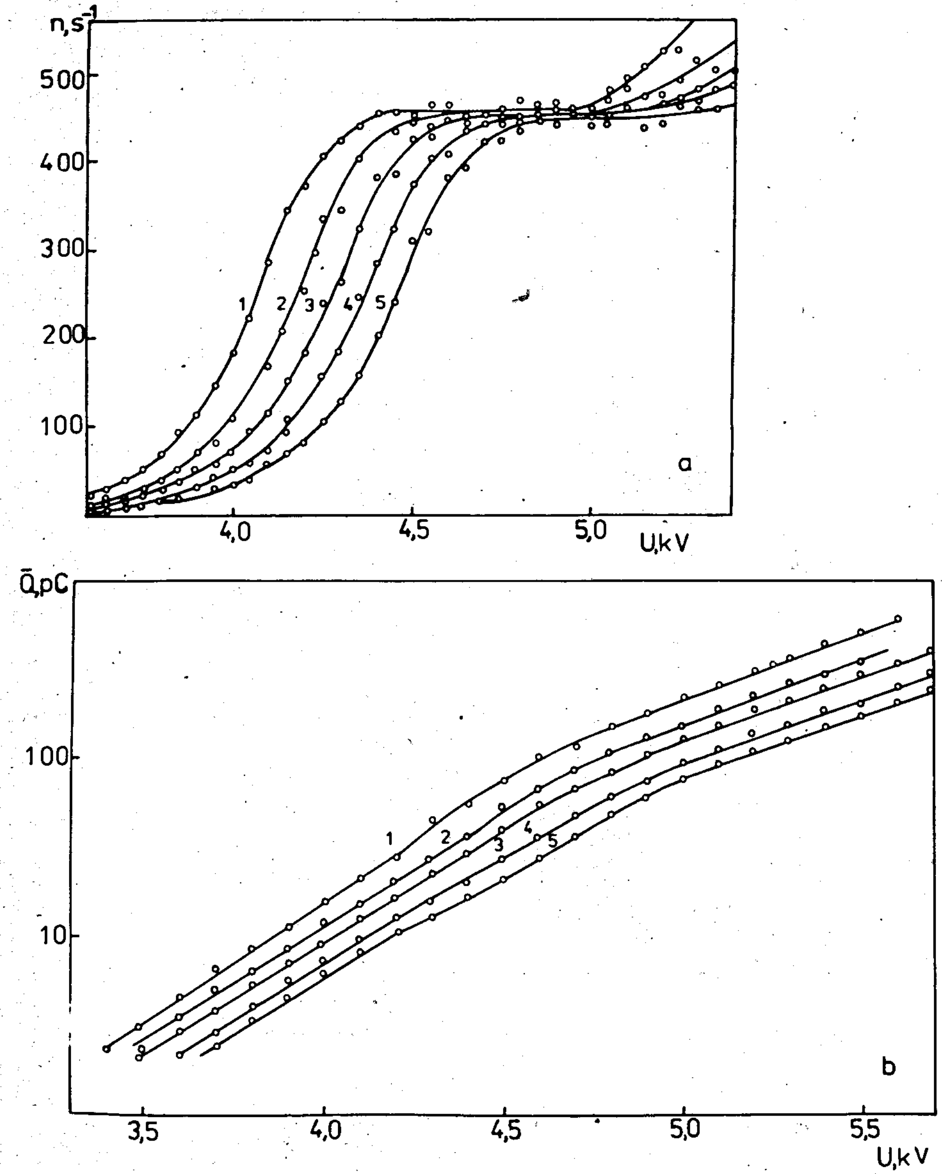


Fig.12. The singles rate (a) and the charge (b) characteristic shift with pressure increase for the Ar:CO_2:iso-C_4H_{10}=10:50:40 mixture:
1. p = 762 Torr.
2. p = 801 Torr.
3. p = 831 Torr.
4. p = 860 Torr.
5. p = 889 Torr.

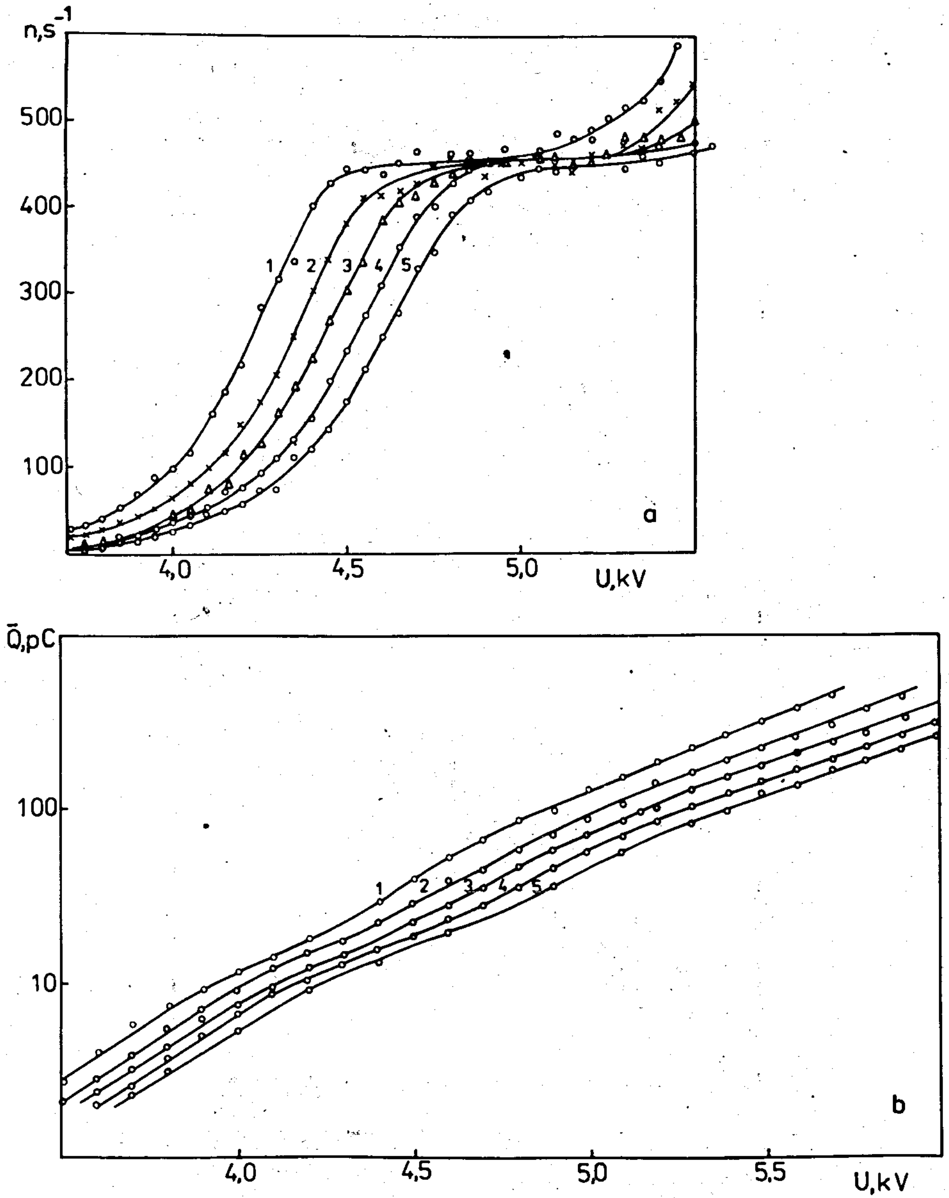


Fig.13. The singles rate (a) and the charge (b) characteristic shift with pressure increase for the Ar:CO_2:iso-C_4H_{10}=5:60:35 mixture:
1. p = 762 Torr.
2. p = 801 Torr.
3. p = 831 Torr.
4. p = 860 Torr.
5. p = 889 Torr.

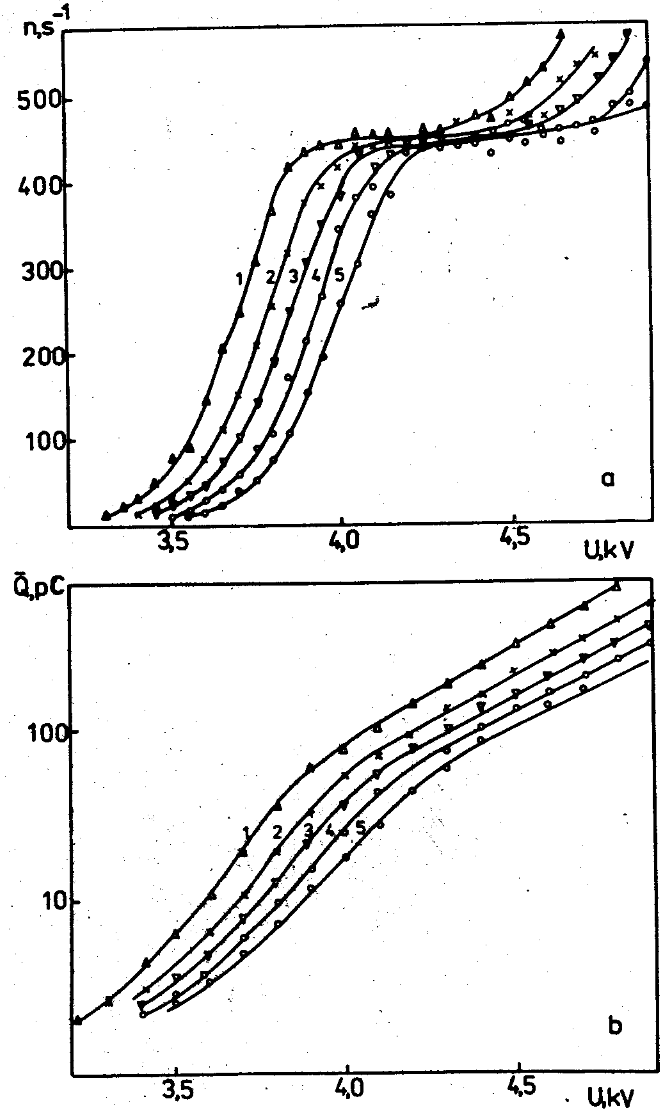


Fig.14. The singles rate (a) and the charge (b) characteristic shift with pressure increase for the Ar:CO_2 :iso-C_4H_{10}=15:60:25 mixture:

1. p = 766 Torr.
2. p = 805 Torr.
3. p = 834 Torr.
4. p = 864 Torr.
5. p = 893 Torr.

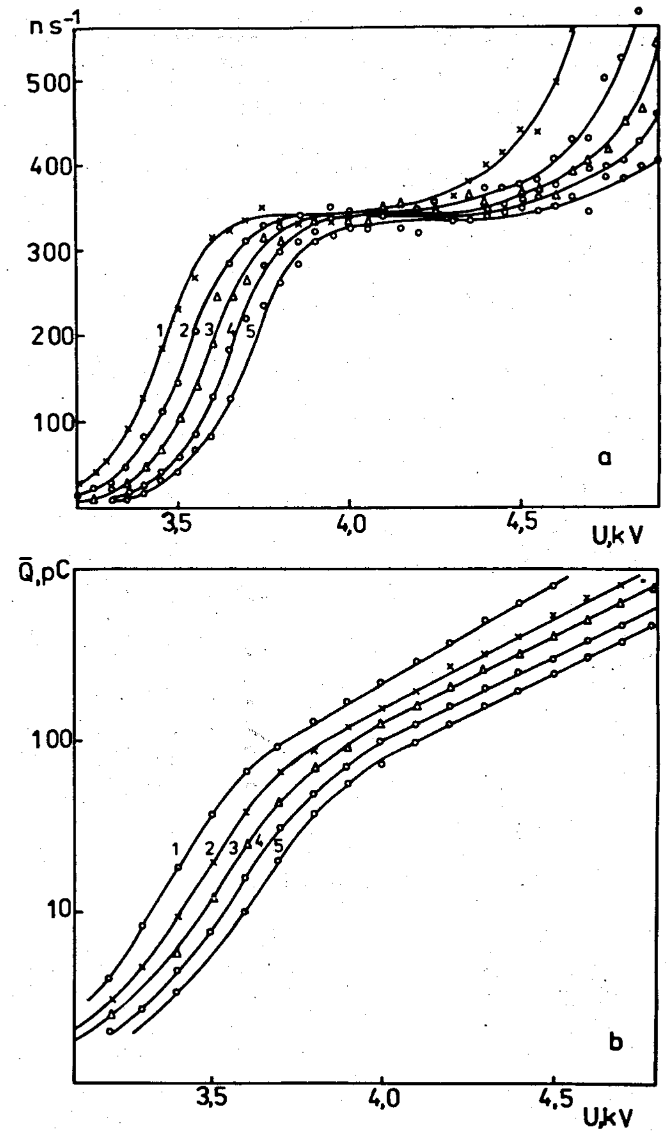


Fig.15. The singles rate (a) and the charge (b) characteristic shift with pressure increase for the Ar:CO_2 :iso-C_4H_{10}=30:40:30 mixture:

1. p = 766 Torr.
2. p = 805 Torr.
3. p = 835 Torr.
4. p = 864 Torr.
5. p = 894 Torr.

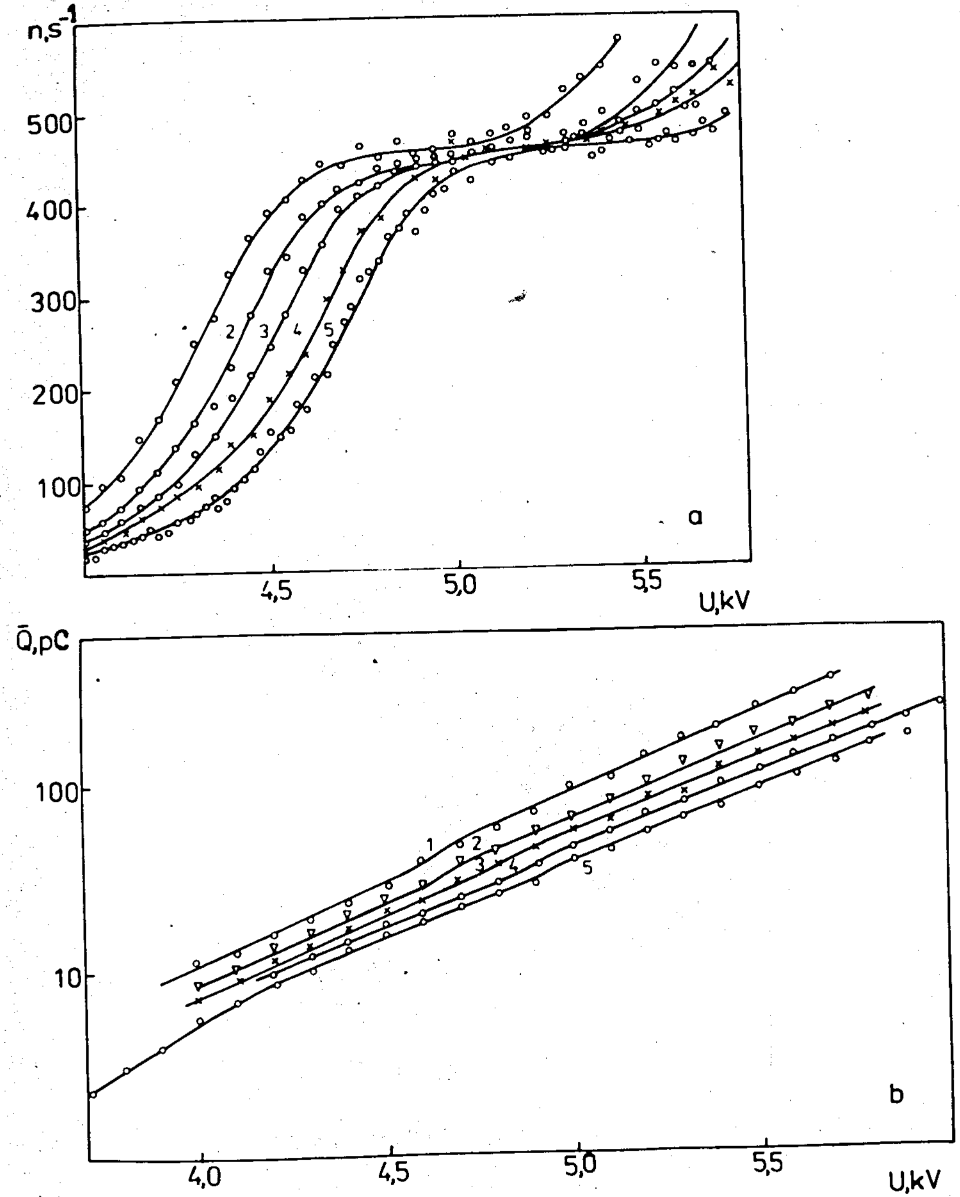


Fig.16. The singles rate (a) and the charge (b) characteristic shift with pressure increase for the Ar:CO_2:iso-C_4H_{10}=0:70:30 mixture:

1. p = 764 Torr.
2. p = 803 Torr.
3. p = 833 Torr.
4. p = 862 Torr.
5. p = 891 Torr.

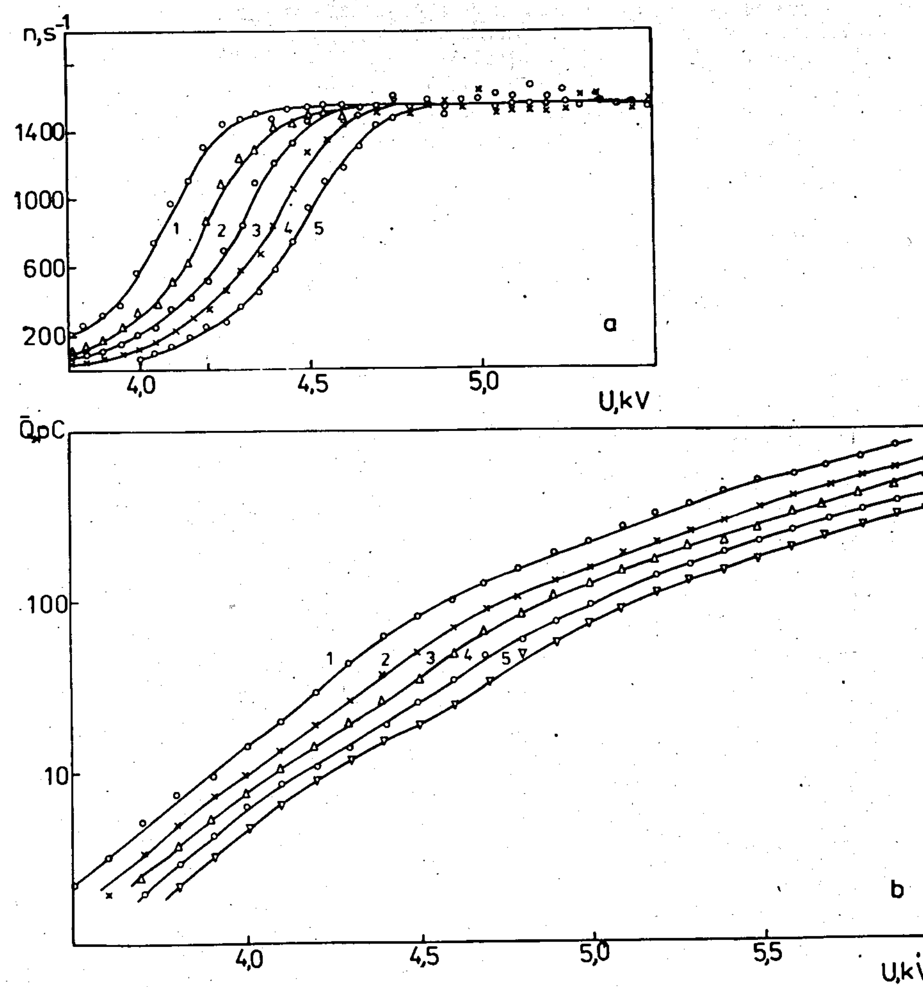


Fig.17. The singles rate (a) and the charge (b) characteristic shift with pressure increase for the Ar:CO_2:iso-C_4H_{10}=25:75 mixture:

1. p = 762 Torr.
2. p = 801 Torr.
3. p = 831 Torr.
4. p = 860 Torr.
5. p = 889 Torr.

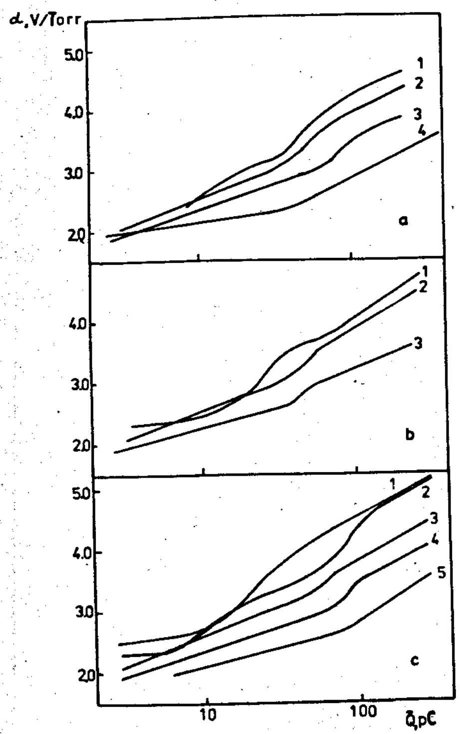
So, if we assume the pressure change scale to be $\Delta p \approx \approx \pm 20$ Torr, the singles rate curve plateau shifts by $\Delta U \approx \pm 50$ V, and the average streamer charge $\bar{Q}$ changes by $\Delta\bar{Q}/Q \approx \mp 20\%$. Such change bears a character of systematic error of energy

Fig.18. The feedback coefficient α vs the average charge $\bar{Q}$ for various component concentrations in the $Ar:CO_2:iso\text{-}C_4H_{10}$ mixture:

a) 1. 0:70:30.
 2. 10:60:30.
 3. 20:50:30.
 4. 30:40:30.

b) 1. 5:60:35.
 2. 10:60:30.
 3. 15:60:25.

c) 1. 25:0:75.
 2. 10:50:40.
 3. 15:50:35.
 4. 20:50:30.
 5. 25:50:25.



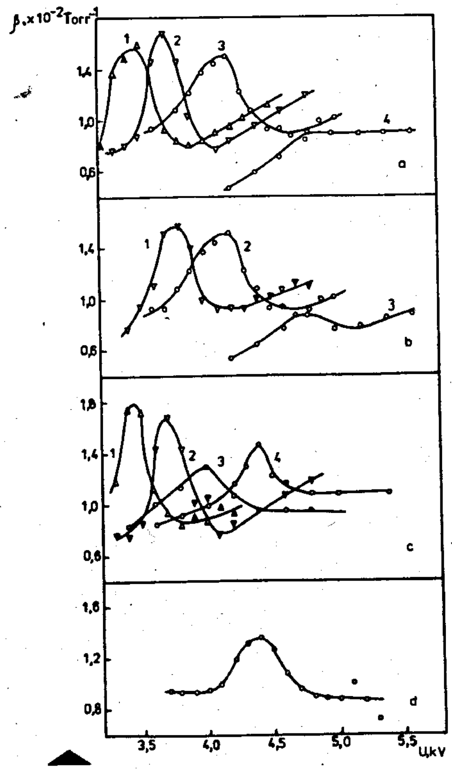


Fig.19. The sensitivity of an average streamer charge the pressure change β vs the high voltage U for various component concentrations in the $Ar:CO_2:iso\text{-}C_4H_{10}$ mixture:

a) 1. 30:40:30.
 2. 20:50:30.
 3. 10:60:30.
 4. 0:70:30.

b) 1. 15:60:25.
 2. 10:60:30.
 3. 5:60:35.

c) 1. 25:50:25.
 2. 15:50:35.
 3. 20:50:30.
 4. 10:50:40.

d) 25:0:75.

measurement and is comparable with the calorimeter energy resolution:

$$\frac{\Delta E}{E} \approx \frac{80\%}{\sqrt{E}} \approx 8\text{-}10\% \text{ for } E \approx 100 \text{ GeV}.$$

That's why it's necessary to monitor the atmospheric pressure and the change in the streamer charge (calorimeter response). This monitoring can be accomplished either in the on-line mode by high voltage tuning in conformity with the feedback coefficient α, or in the off-line mode by the calorimeter response correction.

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REFERENCES

1. DELPHI Technical Proposal. CERN/LEPC/83-66-
2. Lapin V., Obraztsov V. DELPHI 85-59, CAL-14, CERN, 1985.

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