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Studies of Cathode Materials for the LSDT

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Abstract:

We have studied the effects of different cathode materials and gases on the production of secondary pulses in the Limited Streamer Drift Tubes (LSDT). We find that the metallic cathodes, Al, Ni, Cu, Ag, give about the same results. A carbon coated cathode reduces the occurence of these pulses considerably with respect to the metals. The gases, CF_4, CO_2, and Isobutane, give reduced secondary emission in that order.

I. Introduction

The limited streamer drift tube (LSDT) proposal for the GEM muon system has as assets large pulses, fast rise times, small intrinsic time jitter[1] by using the first electrons to arrive at the wire. The large charge gain achieved in this mode requires an effective quenching gas to prevent UV light, produced by recombination and deexcitation in the ionization avalanche, to reach the cathode surface. The UV can knock electrons out of this cathode surface which will drift to the anode wire and initiate another avalanche; a charactristic of this phenomenon is the observation of these secondary pulses arriving later from the initial one by the drift time from cathode to anode.

This effect is not desireable; it adds extra pulses of no physics use and more charge gain which may speed the deterioration of the tube. This effect will depend on the gain of the avalanche (so, the high voltage on the anode wire), the nature of the quenching gas, and the nature of the cathode. In order to investigate this phenomenon with a view to optimize the operation of the proposed streamer tube system, we initiated an experiment to examine the effect of all these variables.

II. Setup and Measurements

A schematic of the experimental setup is shown in Figure 1. There is a gas mixer (Datametrics Model 1511), 2.2 cm x 2,2 cm x 22 cm long Aluminum tubes with different cathode surfaces, HV supply, a LeCroy QVT, readable through a Camac system into a PC. The QVT runs gated, the gate being triggered by the tube pulses and the gate delay set to examine the initial pulse or any time selection of subsequent secondary pulses. The disposition of the gate is illustrated in Fig. 2. The first gate is 150 nsec wide and covers the first pulse and terminates before the arrival of the second pulse; the second gate then starts,is 900 nsec long, and covers the secondary pulse(s).

The cathode surfaces chosen and their work functions (listed in Handbook of Chemistry and Physics) were:

Material	Work function (ev)
Aluminum	2.98-4.36
Carbon coating	4.81
Copper	4.07-5.1
Nickel	3.67-5.01
Silver	3.67-4.63

The spread in values for the work function gives one some idea how this may vary as a function of the preperation of the surface, the crystalographic surface presented, and, in our case, additional variables in the degree of oxidation and cleanliness of surface and gas.

For each tube type we measured the pulse height distribution in charge of the primary and then the secondary pulses as a function of high voltage over the streamer tube regime (usually, 5.0 kV to 5.8 kV). For each tube we also used three different gases:

1.) "IB": 25% Argon, 75% Isobutane

2.) "CO_2": 2% Argon, 9.5% Isobutane, 88.5% CO_2

3.) "CF_4": 11% Isobutane, 20% CO_2, 69% CF_4

Each tube had a small window (with cover glass) to allow the penetration of the 5.2 keV X-rays from an Fe^{55} source. Such a source is preferable to an ionizing track which could give multiple primary pulses from the distributed ionization.

III. Results

A. Typical results

Pulse height in charge distributions from a set of typical runs is shown in Figure 3; we show side by side the distributions, a), in first and main pulse and, b), in the secondary pulses. The peak in the low channels for b) is due to the residual tail of the main pulse; the pulses at higher amplitudes are due to the true second pulse or pulses. The scales are arbitrary.

One can see already that there is not much difference in behaviour between the cathodes of different metalic coatings; however, the tube with a carbon coating shows less propensity for making a secondary pulse compared to the others.

B. After pulse probability

In order to illustrate the differences between cathode material and between gases we show in Figure 4 the probability of the presence of a second pulse(s) as a function of high voltage for the two gases; a) IB, b) CO_2. We did not plot this for CF_4 since there is always a second pulse in that case. Note that the carbon coated tube is much less likely to produce the secondary pulses whereas the other tube materials are not very different in this respect.

C. Charge and extra charge

In order to intercompare gases and obtain a quantitative measure of the pulses we have calibrated our system to give the value in Coulombs of the charge pulses we are measuring. The results are shown in Figure 5 where the main pulse amplitude distribution is shown measured in Coulombs and for the various gases. The cathode material should not and does not enter as a variable.

A consideration in the aging of the wire is the composition of the gas[2] and the total integrated charge per cm deposited on the wire over time; the secondary pulses besides adding noise also can contribute to this aging process. One can observe from Fig. 3 that the secondary pulses are approximately the same size as the first, at least, when their multiplicity is low; the change with higher voltage is the probability of production. We plot in Figure 6 the ratio of charge in the secondary pulse(s) to that in the first as a function of high voltage; this is a measure of unneccesary charge born by the wire, which one would wish to keep to a minimum.

IV. Conclusions

Our main conclusion is that the use of carbon coating on the streamer tubes appears to be very beneficial in suppressing the production of secondary pulses from the cathodes compared to the metallic surfaces. The reason for this escapes us for the present. It is not a consequence of a difference in work function (see Table above) since there is very little difference in this between carbon and the other materials used.

A second conclusion, which was already well known, is that isobutane is a better quencher than CO_2 or CF_4. In turn, CO_2 is a better quencher than CF_4.

References

1.) A. H. Walenta, Proceedings of Summer Institute on Particle Physics, SLAC Report, July 1983.

2.) J. Va'Vra, NIM A252, 547 (1986) and references contained therein;I. Juricic and J. Kadyk, *Wire Chamber Aging*, LBL Workshop, April 1986; J. P. Venuti and G. B. Chadwick, SLAC-PUB-4772, Oct. 1988.

Figures

Fig. 1 A schematic representation of the experimental layout for the tests on various cathode materials

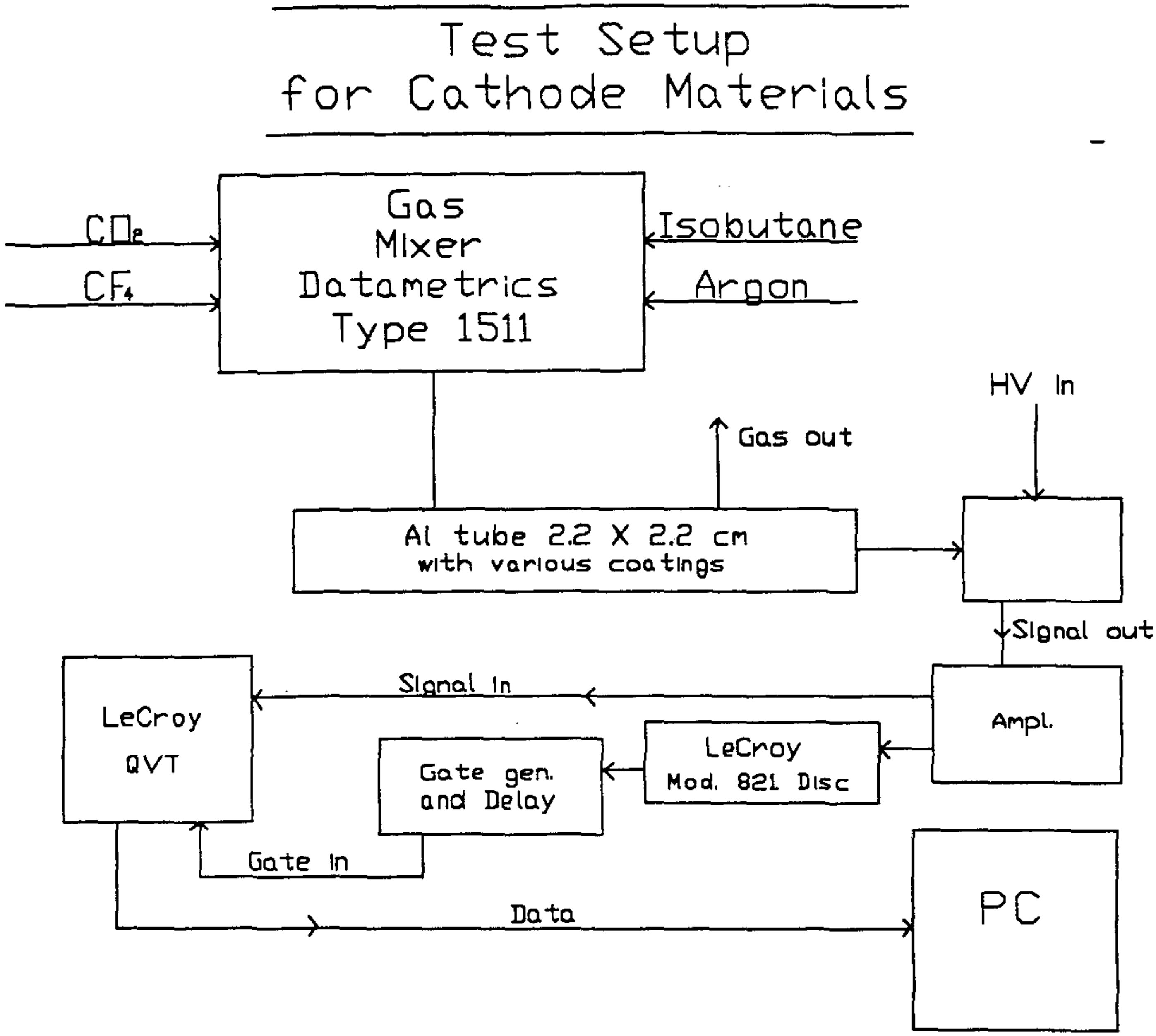
Fig. 2 Schematic of the timing gates for pulse height analysis of the first pulse (Gate 1) and secondaries (Gate 2).

Fig. 3 Typical plots of pulse height (in charge) distribution for, a), first and, b), secondary pulse(s) for various cathode materials. The high voltage was always 5.7 kV; the gas was "CO_2".

Fig. 4 Probability of no after pulse(s) as a function of high voltage and for all cathode materials tested; a) CO_2 , b) IB. The plot for CF_4 is not shown; there was always an afterpulse.

Fig. 5 Absolute value of the average charge in the first pulse vs. high voltage; a) IB, b) CO_2, c) CF_4. In principle the first pulse amplitude should be independent of the cathode material which does not appear to be the case for the CF_4 gas. We have no explanation for this.

Fig. 6 Ratio of average charge in afterpulse(s) to average charge in first pulse as a function of high voltage. a) IB, b) CO_2, c) CF_4.



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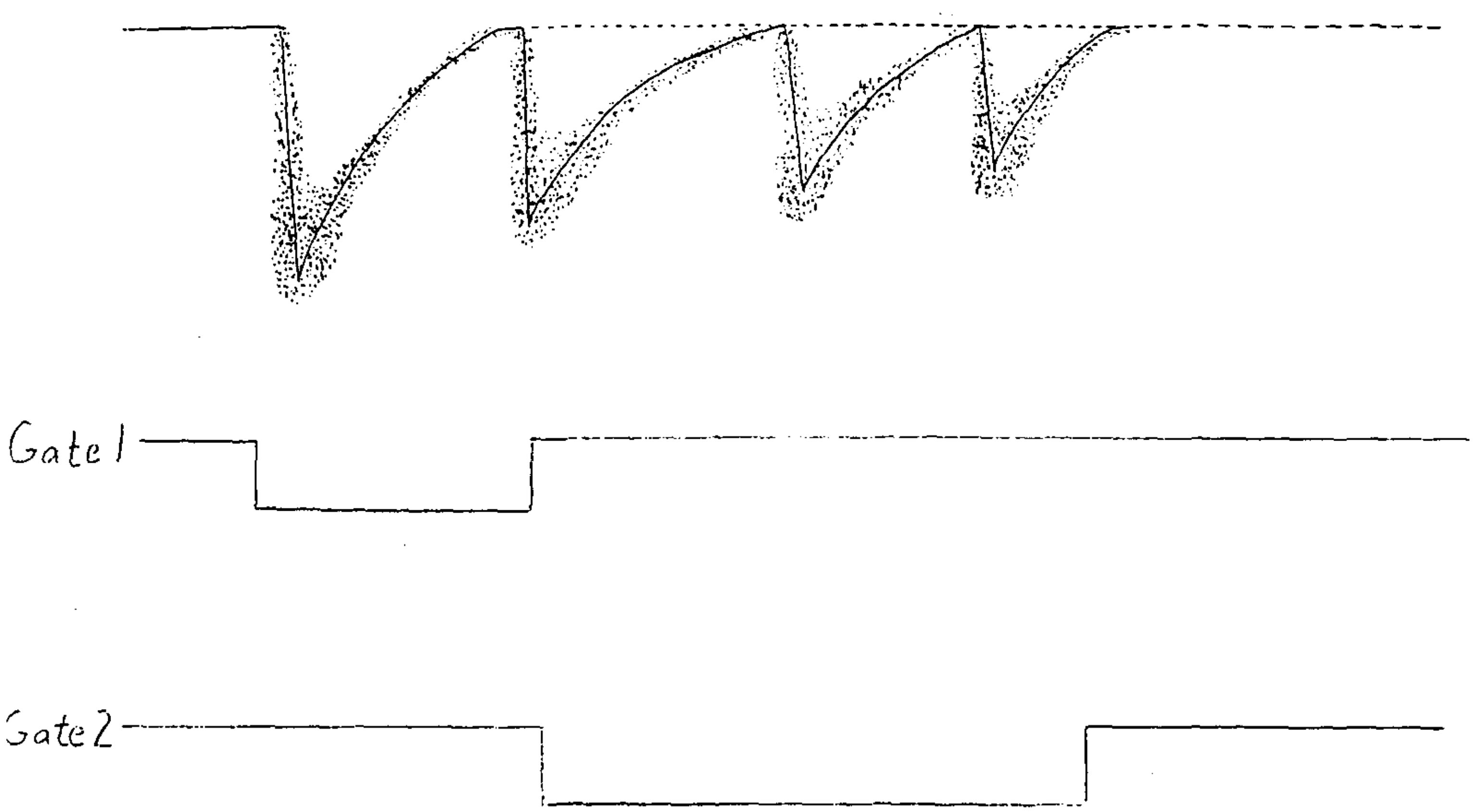

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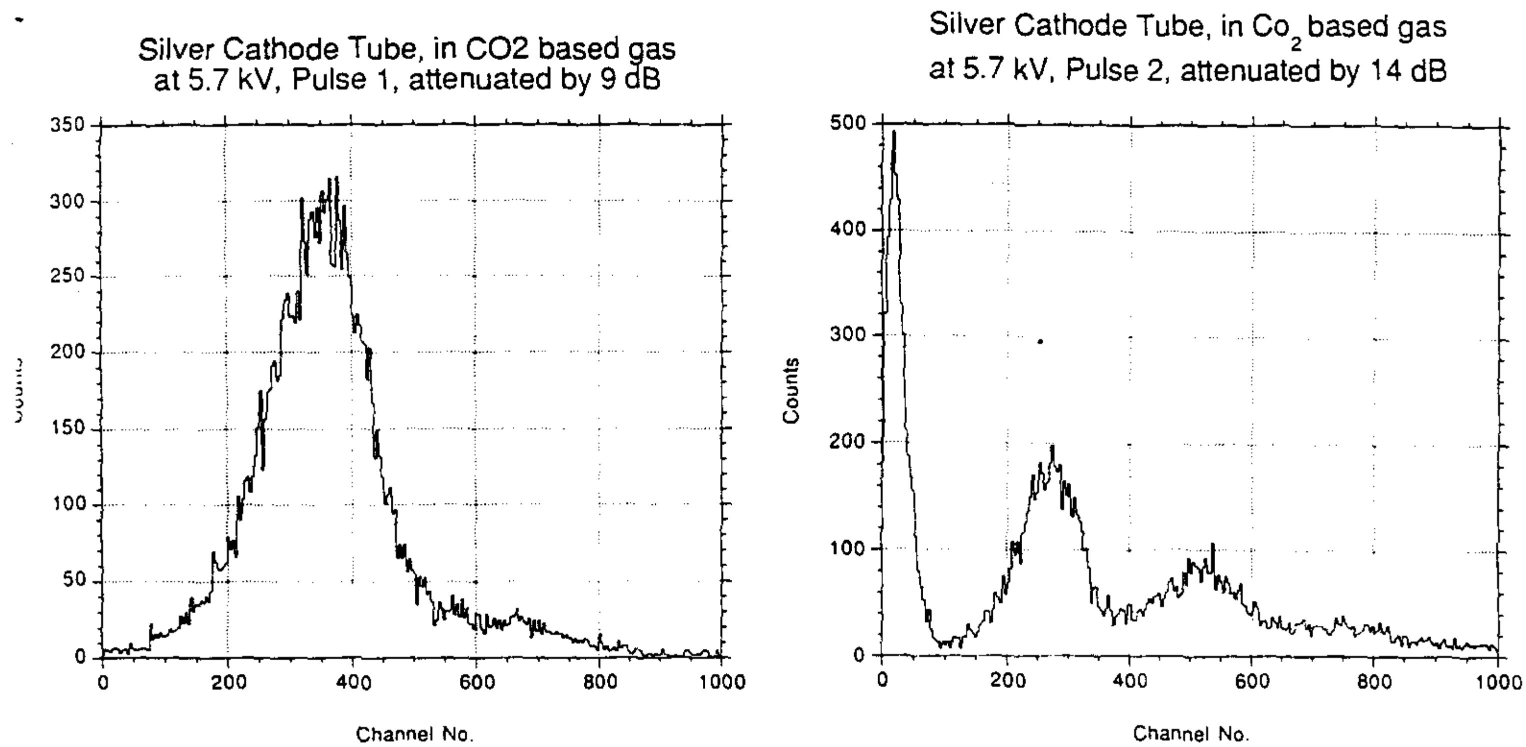

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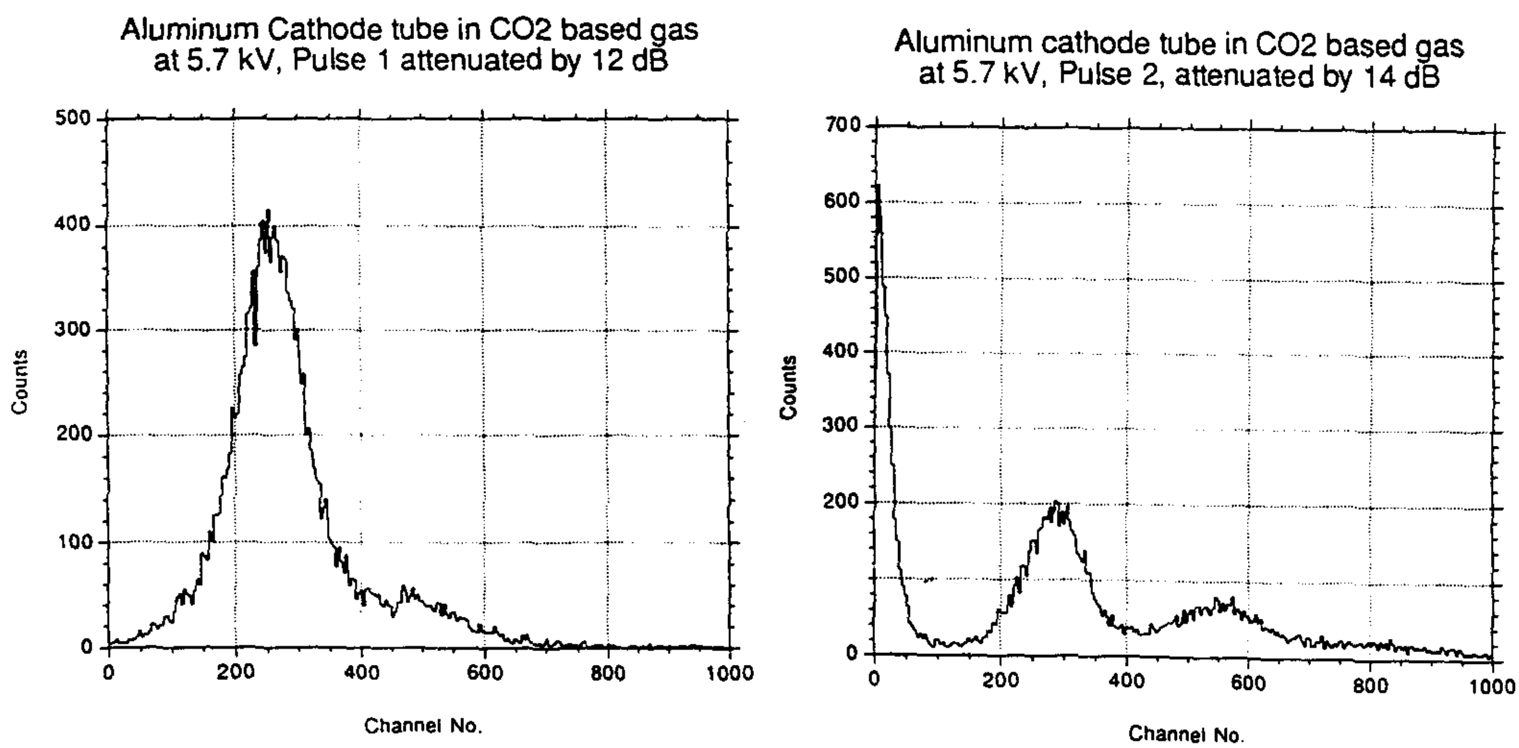
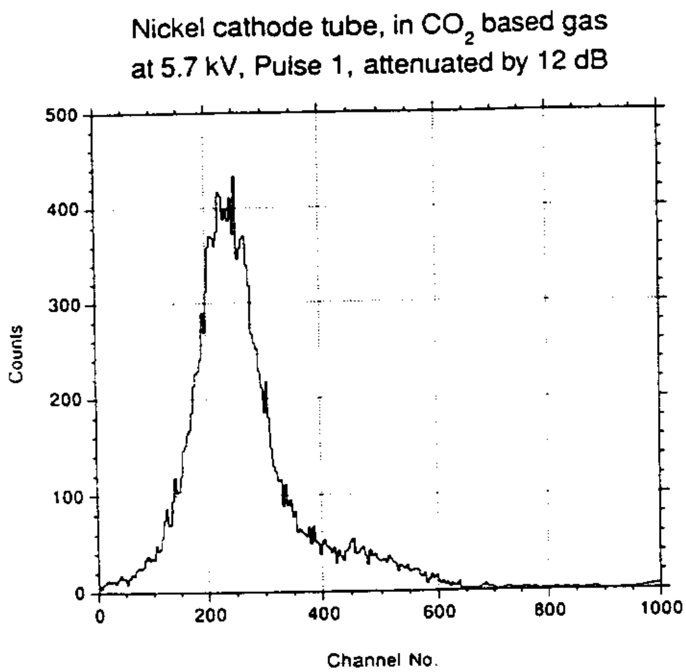
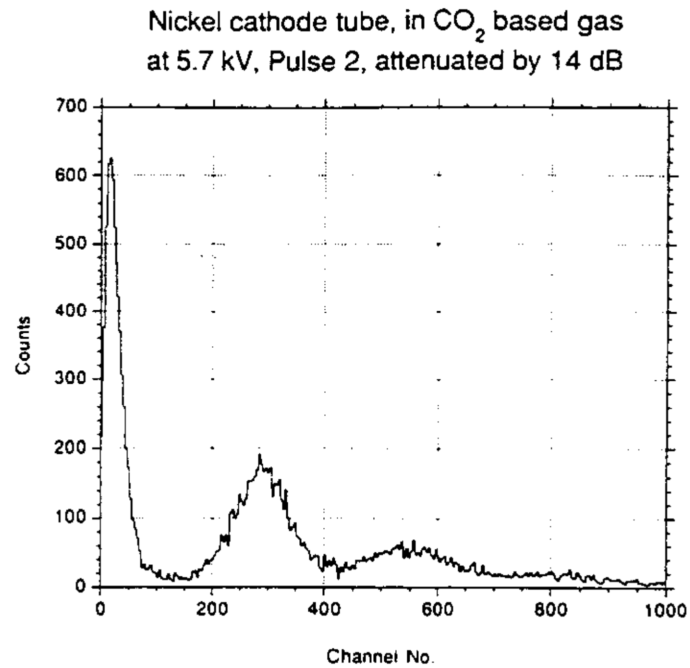
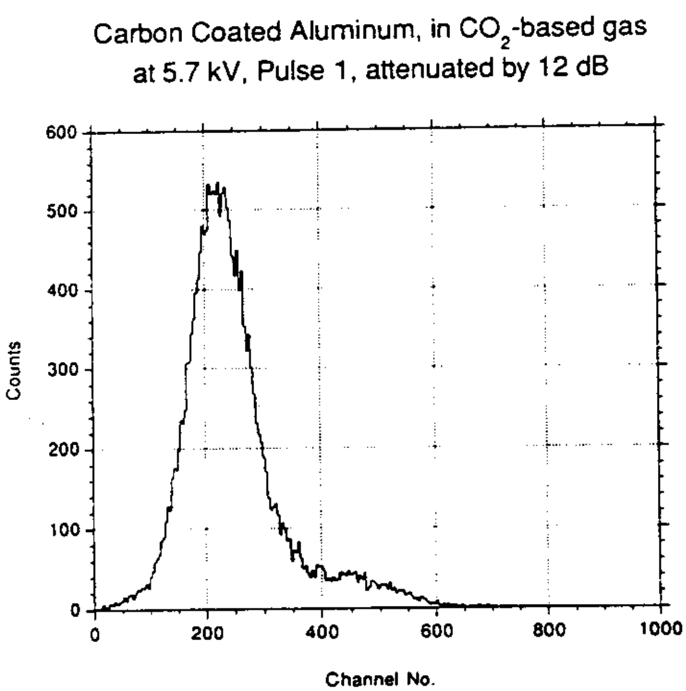
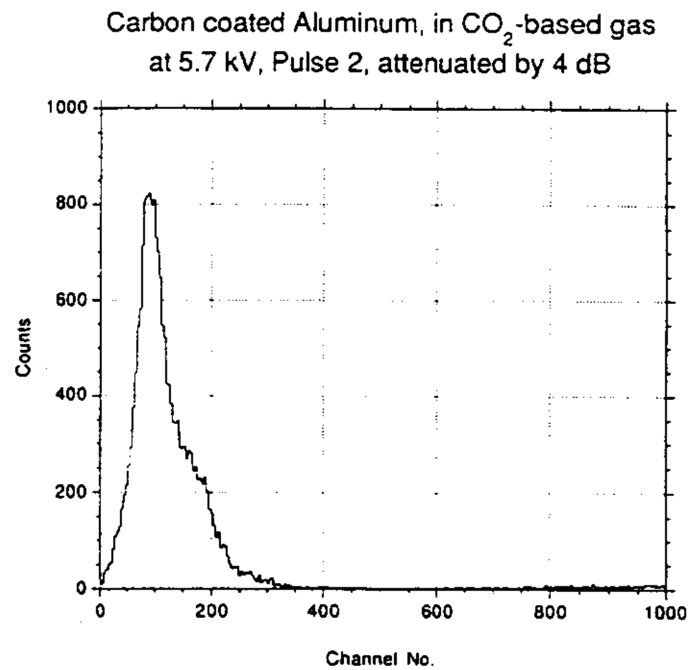
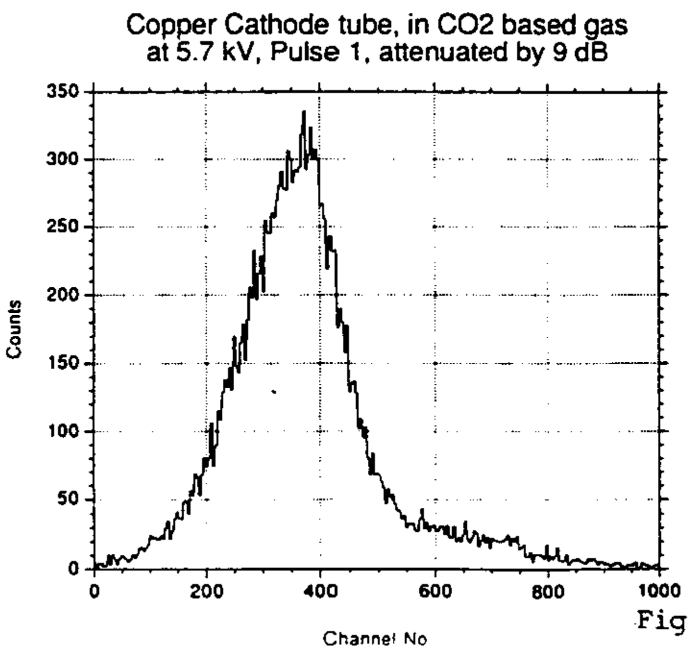



Nickel cathode tube, in CO_2 based gas
at 5.7 kV, Pulse 1, attenuated by 12 dB
Counts
Channel No.


Nickel cathode tube, in CO_2 based gas
at 5.7 kV, Pulse 2, attenuated by 14 dB
Counts
Channel No.


Carbon Coated Aluminum, in CO_2-based gas
at 5.7 kV, Pulse 1, attenuated by 12 dB
Counts
Channel No.


Carbon coated Aluminum, in CO_2-based gas
at 5.7 kV, Pulse 2, attenuated by 4 dB
Counts
Channel No.


Copper Cathode tube, in CO2 based gas
at 5.7 kV, Pulse 1, attenuated by 9 dB
Counts
Channel No

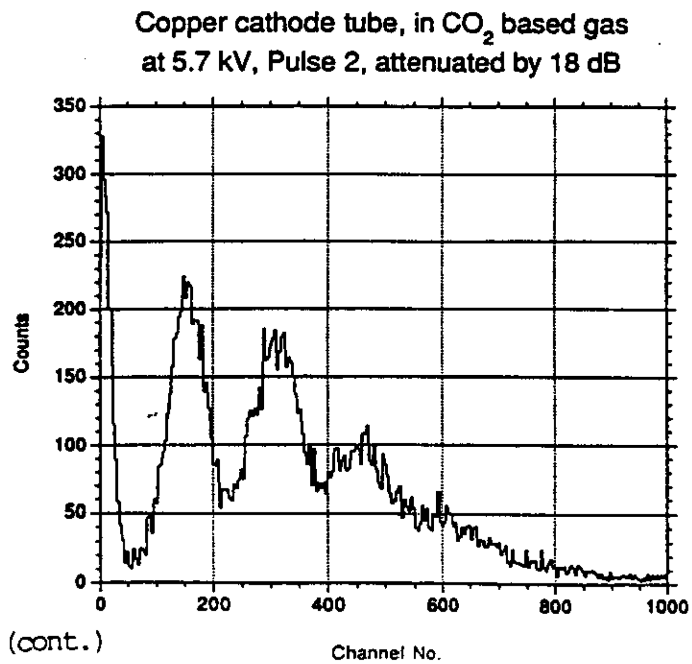
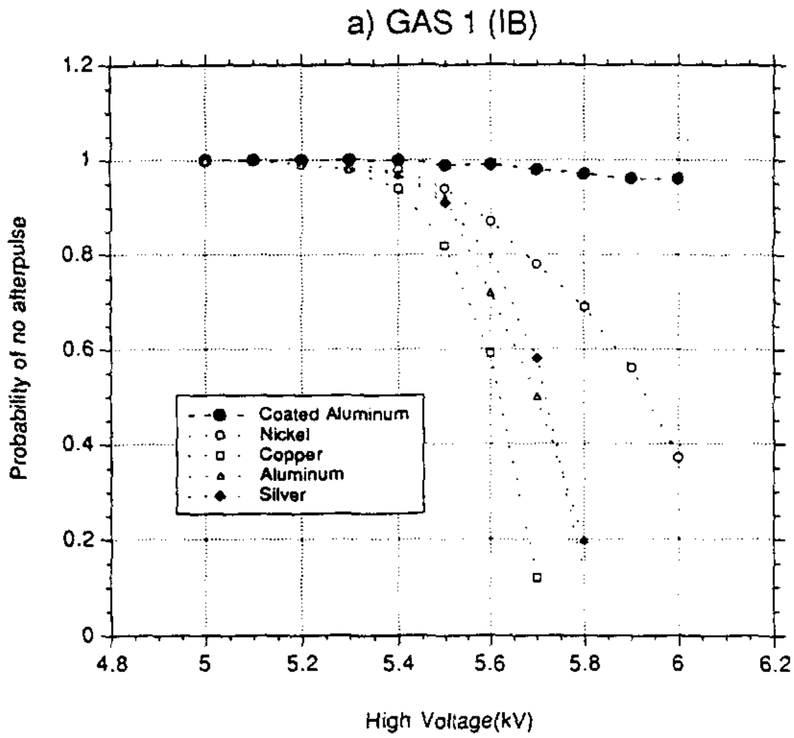
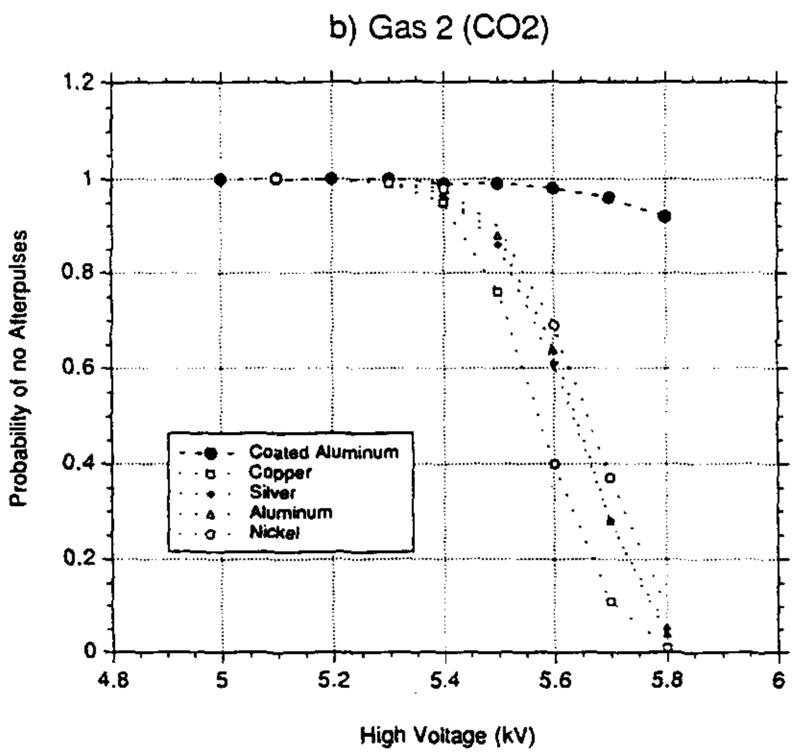

Copper cathode tube, in CO_2 based gas
at 5.7 kV, Pulse 2, attenuated by 18 dB
Counts
Channel No.

Fig. 3 (cont.)





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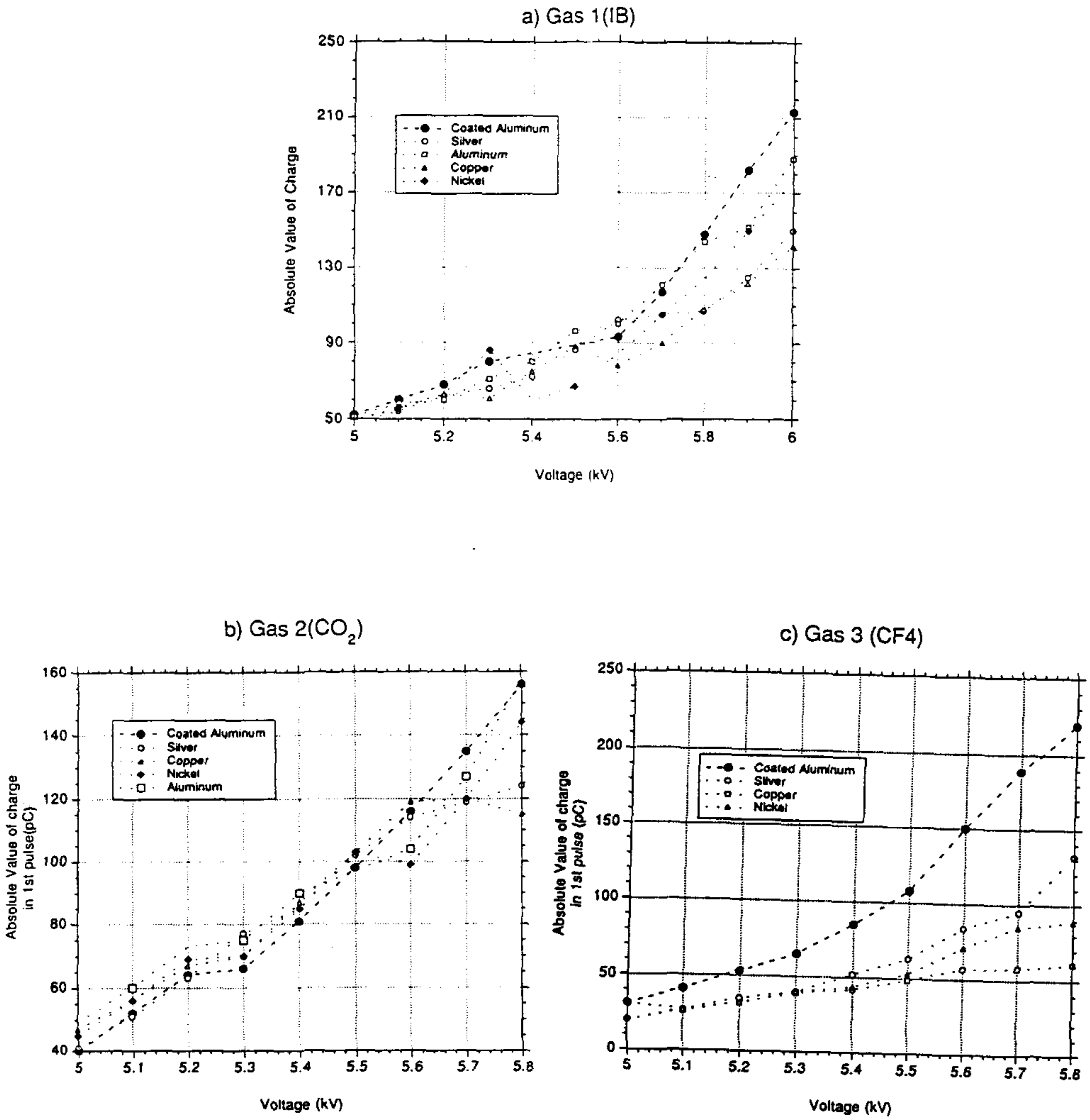

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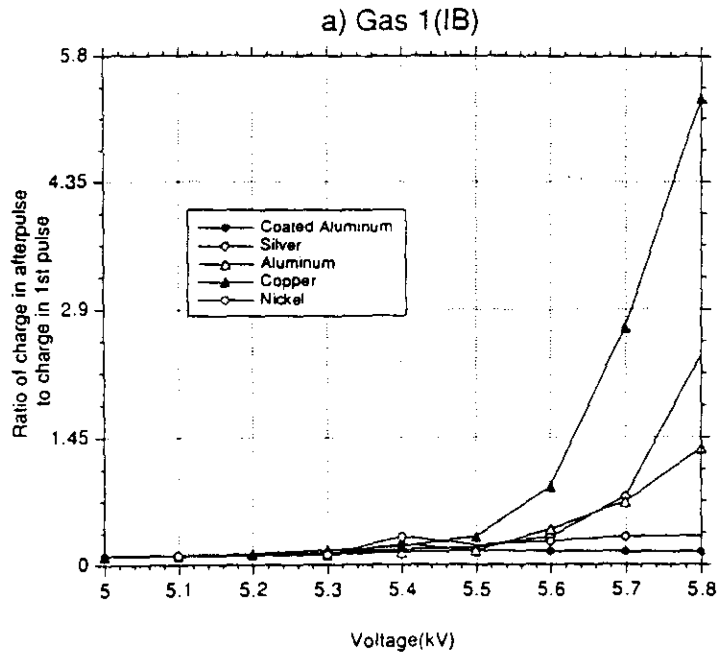

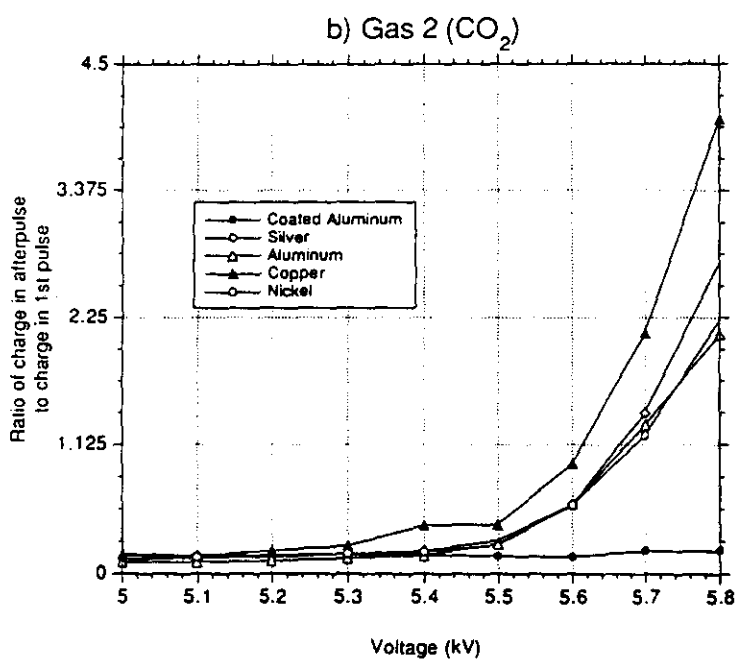

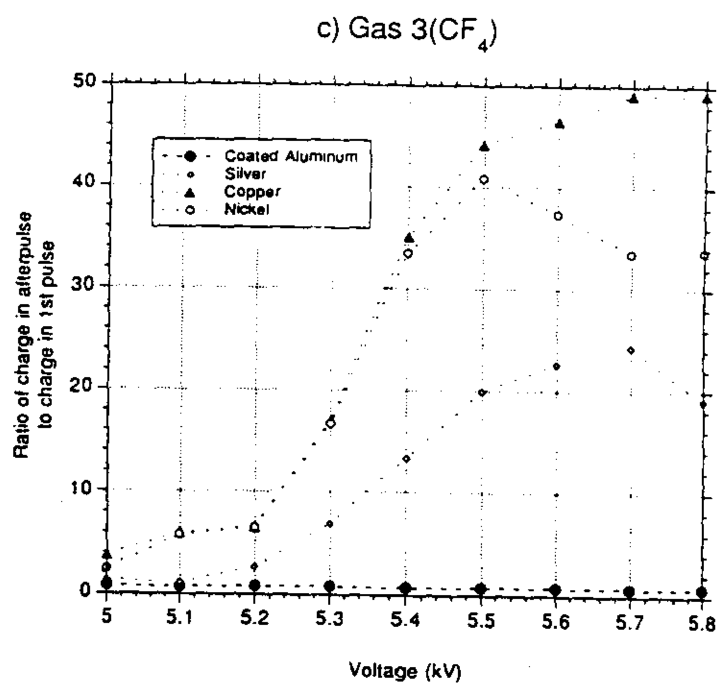

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