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# Influence of the Admixture of Argon on the Characteristics of Geiger-Müller Counters Filled with a Mixture of Neon and Ethyl Acetate, or with Neon and Ammonia

## Wpływ domieszek argonu na charakterystyki liczników Geigera-Müllera napełnionych mieszaniną neonu z octanem etylu i neonu z amoniakiem

## Влияние примесей аргона на характеристики счётчиков Гейгера — Мюллера, наполненных смесью неона с этил — ацетатом и неона с аммиаком

## INTRODUCTION

Investigations of the lowering of the operating voltage of the non-halogen Geiger—Müller counters by the use of special mixture of filling gases were carried out by many authors. A. Trost [1] studied counters filled with mixture of neon and argon with the addition of a small quantity of oxygen (ca. 1 torr). The counters possess quenching properties and when the operating potential is low, they have satisfactory characteristics. Admixing tetra-methyl-lead $Pb(CH_3)_4$ to the argon or argon-methane counters at almost atmospheric pressure allows to attain low starting potential [2]. J. A. Simpson [3] investigated starting potentials in counters filled with neon plus a small quantity of argon amounting to 0.01 per cent of the total pressure of the filling gas. He made counters with operating voltage ranging from 115—135 volts. H. Friedman [4] made similar counters with the addition of 1 torr

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of ethyl acetate possessing self-quenching properties. Their starting potentials approximated ca. 350 volts and the length of the plateau was 100—150 volts.

The aim of this paper is the investigation of the influence of admixing considerable quantities of argon (to 10 torrs) on the height of the starting potential, the length and the slope of the plateau in Geiger—Müller counters filled with neon and ethyl acetate, or with neon and ammonia.

## APPARATUS AND THE CONSTRUCTION OF COUNTERS

To get necessary vacuum there were used a rotary pump and a two-stage mercury diffusion pump. The mercury vapours were not trapped. Gaseous pressures were measured by Pirani manometer and by a shortened mercury manometer.

The filling gas was prepared using spectrally pure neon and argon, technical ammonia, and water-free ethyl acetate. Before filling to outgas them the counters were heated for one hour in a vacuum to the temperature of ca. 150°C. The components of the filling mixture were introduced to the apparatus with successively growing percentages of the gas mixture. After preparing the necessary mixture the counters were connected with the apparatus for two hours to equalize the partial pressures of the fillings in each counter.

The counters chosen for the investigation are of a bell-type with a mica window [5]. The axial section of the counter is shown in Fig. 1. The anode wire is strained by using a transversal steel wire on the mica window side. The cathodes of the counters are made of brass tubes; the inside diameter is 22 mm. The anodes of tungsten wire have the diameter of 0.1 mm. The active length of the anode in each counter is ca. 25 mm. Glass parts and windows were stuck to brass with „Araldit".

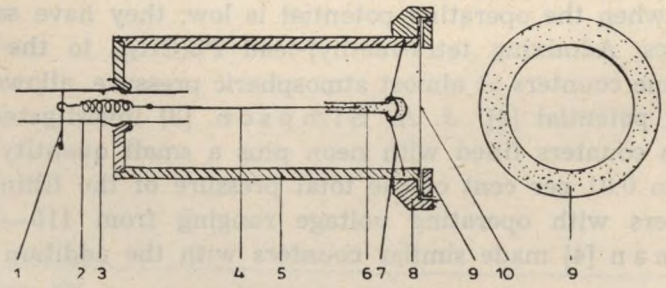


Fig. 1. Axial section of the counter: 1 — tungsten cross-bar, 2 — glass tube, 3 — steel wire, 4 — tungsten anode, 5 — cathode, 6 — capillary tube isolating anode, 7 — steel cross-bar, 8 — window frame, 9 — pressing ring, 10 — mica window

Characteristics of the counters were recorded after the equalizing of the starting potential in each counter connected with the apparatus, and were then checked by means of a synchroscope.

## THE DATA OF MEASUREMENTS

### A) COUNTERS FILLED WITH NEON AND ETHYL ACETATE WITH AN ADMIXTURE OF ARGON

The total pressure of filling gases in the counters was fixed at 80 torrs in each tube. Characteristics for all kinds of fillings containing 3, 6, 8 and 10 torrs of ethyl acetate and 0.1, 1.5 and 4 torrs of argon were studied. There were measured: starting potentials, lengths and slopes of the plateau. The data of measurements are presented in Table 1 in such a way that they form four groups of characteristics, each containing characteristics of counters with stable quantity of ethyl acetate and different addition of argon. For comparison each family

Table 1. The characteristics of counters with ethyl acetate

| Family | Characteristic | Composition of the filling gas (torrs) | | | Starting potential (volts) | Length of the plateau (volts) | Slope of the plateau (%)/100 volts |
|---|---|---|---|---|---|---|---|
| | | Ethyl acetate | Ne | Ar | | | |
| I | 1 | 3 | — | 77 | 860 | 100 | 4 |
| | 2 | 3 | 77 | — | 800 | 100 | 6 |
| | 3 | 3 | 77 | 0.1 | 780 | 90 | 14 |
| | 4 | 3 | 75.5 | 1.5 | 740 | 80 | 20 |
| | 5 | 3 | 73 | 4 | 720 | 30 | 22 |
| II | 1 | 6 | — | 74 | 1120 | 190 | 5 |
| | 2 | 6 | 74 | — | 1000 | 180 | 4 |
| | 3 | 6 | 74 | 0.1 | 940 | 170 | 4 |
| | 4 | 6 | 72.5 | 1.5 | 860 | 80 | 6 |
| | 5 | 6 | 70 | 4 | 820 | 80 | 6 |
| III | 1 | 8 | — | 72 | 1230 | 280 | 4 |
| | 2 | 8 | 72 | — | 1080 | 210 | 3 |
| | 3 | 8 | 72 | 0.1 | 1060 | 150 | 4 |
| | 4 | 8 | 70.5 | 1.5 | 1000 | 130 | 4 |
| | 5 | 8 | 68 | 4 | 920 | 130 | 5 |
| IV | 1 | 10 | — | 70 | 1360 | 320 | 3 |
| | 2 | 10 | 70 | — | 1220 | 240 | 2 |
| | 3 | 10 | 70 | 0.1 | 1200 | 240 | 2 |
| | 4 | 10 | 68.5 | 1.5 | 1140 | 240 | 2 |
| | 5 | 10 | 66 | 4 | 1040 | 240 | 2 |

possesses the data for characteristics of the counter filled with argon and proper for the family percentage of ethyl acetate without neon.

It was observed that the low starting potentials in each group (I, II, III, IV) of counters were reversely related to argon admixtures. The most considerable lowering was obtained at the partial pressure of 4 torrs. The presence of argon in the mixture of neon and ethyl acetate results in a decrease of those energies at which electrons occur and avalanches start. The ionisation energy of neon (21.5 eV) is greater than that of argon (15.7 eV). The result is that discharges may appear even when lower potential is applied. Collisions of the second kind between the excited atoms of neon (Ne*) and argon initiate the ionization of argon. The interchange of energies of that kind occurs according to the scheme:

$$Ne^* + Ar \rightarrow Ne + Ar^+ + e$$

The probability of such ionization of argon atoms increases with the number of introduced argon atoms. Figure 2 presents the plot of the starting potentials $U_p$ versus ethyl acetate concentration for different amounts of argon additions.

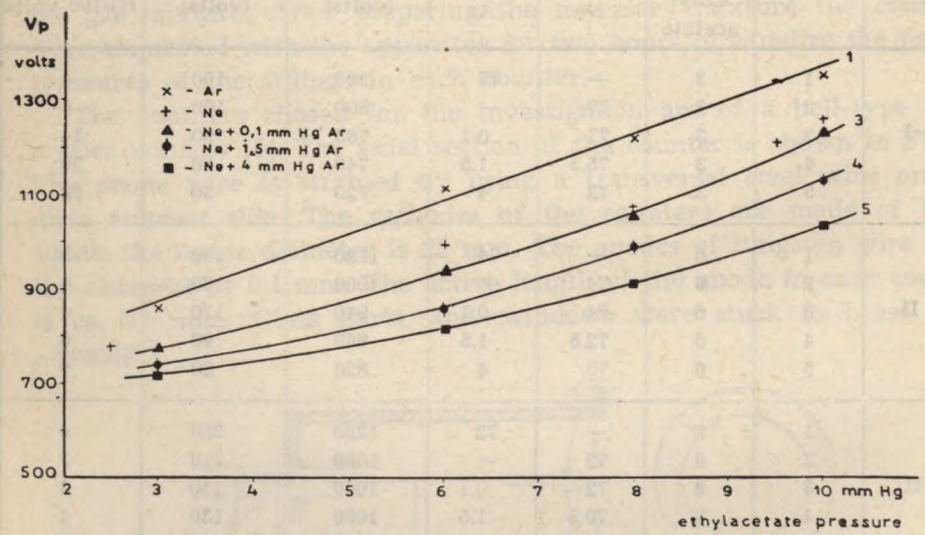


Fig. 2. Starting potentials vs. ethyl acetate concentration for different argon admixtures

The lowest starting potentials were obtained when the argon partial pressure was 4 torrs. A decrease of this parameter is approximately 20 per cent in comparison with that without argon.

The increase of the percentage of ethyl acetate in the constituent of the filling gas caused the rise of the starting potentials. Thanks to a greater number of ethyl acetate molecules in the mixture the amount of unelastic collisions occurring between their molecules and primary electrons increased. In the collisions electrons lose their energies exciting the rotational and vibrational levels of the molecules. They do not gain enough energy to produce avalanche ionization until the counter voltage is sufficiently high.

The increase of the percentage of argon in the mixtures containing 3, 6 and 8 torrs of ethyl acetate causes a shortening of the plateau of the counters. However, when some definite amounts of the quenching gas (10 torrs) are applied, the shortening of the plateau does not occur (Table 1). Also the slopes of the plateau that rise with the admixture of argon to the mixtures of 3, 6 and 8 torrs of ethyl acetate, remain unchanged (within the range of experimental error) already with the mixture containing 10 torrs of ethyl acetate. Such behaviour of the length and the slope of the plateau is the result of the influence of two factors; the admixture of argon, which possesses a smaller ionization energy in comparison with neon, increases the probability of producing multiple impulses, while higher pressure of ethyl acetate vapours increases quenching properties of the filling gas exercising the effect just opposite to that of argon. It is obvious that by proper choice of right pressures of argon and ethyl acetate optimal parameters of counter characteristics may be obtained.

### B) COUNTERS FILLED WITH NEON AND AMMONIA WITH AN ADMIXTURE OF ARGON

Total pressure of the filling gas in the counters was 100 torrs. Fillings containing 11, 21, 30 and 50 torrs of ammonia and 0.5 and 10 torrs of argon were investigated. The characteristic parameters of the counters with these fillings are presented in Table 2.

The increase of the percentage of argon by weight in the fillings lowers the starting potential of the counters at all studied percentages of ammonia. The mechanism of the influence exercised by argon on this lowering is the same as in counters filled with neon and ethyl acetate. Figure 3 shows the plot of starting potentials $U_p$ versus the percentage of ammonia and argon admixture.

The most considerable lowering of the starting potential was obtained at the filling with 10 torrs of argon in the mixture (approximately 10 per cent). The increase of the pressure of ammonia causes the rising of the starting potential as in the case of other quenching gases.

Table 2. The data of the characteristics of the counters with ammonia

| Family | Characteristic | Composition of the filling gas (torrs) | | | Starting potential (volts) | Length of the plateau (volts) | Slope of the plateau (%)/100 volts |
|---|---|---|---|---|---|---|---|
| | | Ne | Ar | $NH_3$ | | | |
| I | 1 | 89 | — | 11 | 750 | — | 87 |
| | 2 | 84 | 5 | 11 | 730 | 80 | 56 |
| | 3 | 79 | 10 | 11 | 720 | 70 | 32 |
| II | 1 | 79 | — | 21 | 960 | 100 | 55 |
| | 2 | 74 | 5 | 21 | 850 | 90 | 18 |
| | 3 | 69 | 10 | 21 | 820 | 80 | 13 |
| III | 1 | 70 | — | 30 | 1050 | 120 | 51 |
| | 2 | 65 | 5 | 30 | 1000 | 120 | 31 |
| | 3 | 60 | 10 | 30 | 920 | 90 | 19 |
| IV | 1 | 50 | — | 50 | 1220 | 160 | 47 |
| | 2 | 45 | 5 | 50 | 1160 | 130 | 32 |
| | 3 | 40 | 10 | 50 | 1140 | 120 | 32 |

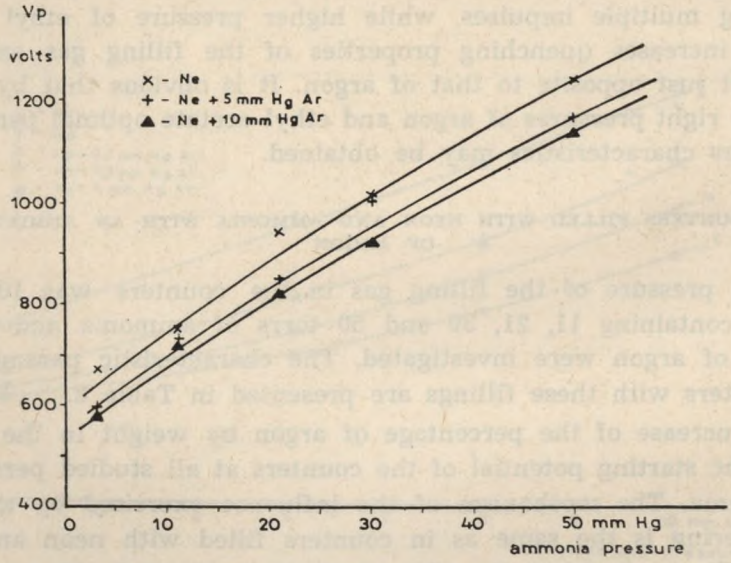


Fig. 3. Starting potentials vs. ammonia concentration for different argon admixtures

The data in Table 2 show that the admixture of argon makes the slope of the plateau smaller. That refers to all families of characteristics. The explanation is that the suppression of metastable states of neon

atoms in collisions with the introduced argon atoms results in diminishing the probabilities of initiating multiple impulses. However, the final interpretation of the changes in the slope and the length of the plateau is difficult, because of a possible influence of impurities contained in ammonia used in the experiments.

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## STRESZCZENIE

Zbudowano kielichowe liczniki Geigera—Müllera, które napełniono neonem z octanem etylu i neonem z amoniakiem z dodatkiem argonu do obu rodzajów napełnień. Stosowano do napełnień domieszki dużych ilości argonu, wynoszących 0,1; 1,5; i 4 Tr w licznikach z octanem etylu oraz 5 i 10 Tr w licznikach z amoniakiem.

Przebadano, jaki wpływ wywiera argon dodany do mieszanin napełniających liczniki G.-M. z neonem i octanem etylu oraz z neonem i amoniakiem (przy różnych zawartościach procentowych octanu i amoniaku) na napięcia progowe, nachylenia i długości plateau liczników.

Stwierdzono obniżkę napięć progowych po dodaniu argonu, zarówno w przypadku liczników z ostanem etylu, jak i z amoniakiem. Stwierdzono również, że dodanie argonu do mieszaniny z małą zawartością procentową octanu etylu powoduje skrócenie plateau liczników i zwiększenie ich nachyleń. Przy większych zawartościach octanu etylu efektu tego nie obserwowano. Domieszka 4 Tr argonu do liczników z 10 Tr octanu etylu i 66 Tr neonu obniża ich napięcie progowe o około 200 V bez ujemnego wpływu na długość (około 240 V) i nachylenie plateau (poniżej 2% na 100 V). Dla liczników napełnionych neonem i amoniakiem ich nachylenia plateau maleją wraz ze wzrostem ilości domieszek argonu. Dobierając odpowiednie ciśnienie cząstkowe argonu i czynnika gaszącego można uzyskać obniżkę napięć progowych liczników przy zachowaniu ich optymalnych charakterystyk.

## РЕЗЮМЕ

Сконструированы торцовые счётчики Гейгера-Мюллера, которые наполнялись неоном с этилацетатом и неоном с аммиаком с добавлением в обоих случаях аргона. Применялись в счётчиках с этилацетатом примеси аргона в больших количествах по 0,1, 1,5 и 4 торра, а в счётчиках с аммиаком по 5 и 10 торров.

Исследовано, какое влияние на пороговое напряжение, наклон характеристики счётчиков и длину ее плато оказывает аргон, прибавленный к смесям неона с этилацетатом или аммиаком.

Констатировано снижение порогового напражения после прибавления аргона в обоих случаях. Установлено также, что прибавление аргона к смеси с малым содержанием этилацстата вызывает сокращение плато счётчиков и увеличение их наклона. При больших концентрациях ацетата этого эффекта не замечено. Прибавление торр аргона счётчикам с 10 торрами этилацетата и 66 торрами неона понижает их пороговое напражение приблизительно на 200V без отрицательного влияния на длину (около 240V) и куртизну плато (ниже 2% на 100V). У счётчиков, наполненных неоном и аммиаком, наклон их плато уменьшается с увеличением примеси аргона.

Подбирая подходящее парциальное давление аргона и гасящего фактора, можно получить понижение пороговых напряжений счётчиков при сохранении их оптимальных характеристик.


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