LIMITATION AND ELIMINATION OF ELECTRON FIELD EMISSION OF THE HIGH VOLTAGE FUSE ELEMENT

Cz.Królikowski, M.Stroiński, H.Mościcka-Grzesiak
W.Górczewski, H.Gruszka

Technical University of Poznań
Electrical Engineering Department
Poznań, Poland

Abstract

In a high-voltage vacuum fuse, a disadvantageous phenomenon of the electron field emission from a wire may occur. This phenomenon can be limited by screening the wire as well as by increasing its smoothness. The paper shows the effect of screening the wire by electrodes, according to the size of the electrodes and their spacing. An improvement of the surface of the wire was obtained by electropolishing. It was found that electropolished wires are characterized by a considerably higher voltage, corresponding to the occurrence of the emission current.

INTRODUCTION

There has been a growing interest in the high voltage vacuum fuse lately. Laboratory investigations have shown that the vacuum fuse has a number of characteristic properties [1, 2, 3, 4, 5, 6]. One of them is breaking the current at the first passing of the current sinusoid through zero. As a result there is a lack of overvoltages in the circuit, and a lack of reignitions. The fuse element is short and the fuse chamber is of small dimensions.

The possibility of the phenomenon occurrence of electron field emission, from the surface of the fuse-element wire, is a defect. The field emission phenomenon is inadmissible, because:

- it causes surface roughening of the wire and a rapidly progressing ageing process of the wire,
- narrowings of the wire occur, which may even result in melting the wire,
- X-radiation is a secondary effect of electron field emission.

In the paper, the possiblities of eliminating and of limiting the phenomena of electron field emission will be presented, using two methods:

- screening the wire by means of two electrodes whose dimensions and spacing are properly chosen,

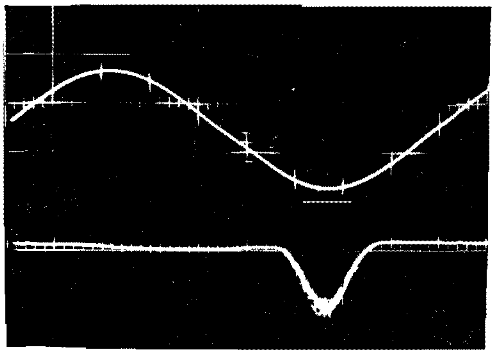

Fig.3. Oscillogram of voltage and emission current from the wire surface

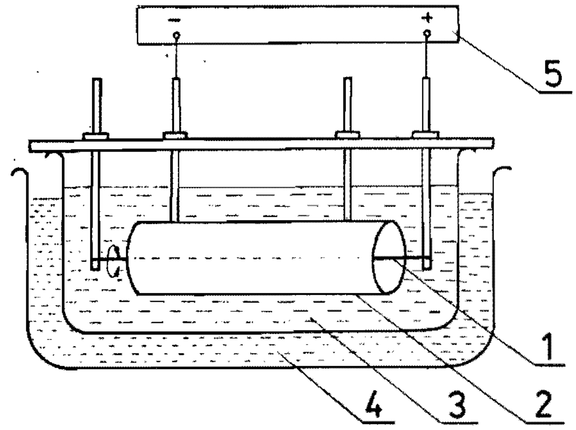

Fig.4. The set for electropolishing the wire, 1-electropolished wire, 2-cylindrical electrode, 3-65% water solution of orthophosphoric acid, 4-water bath, 5-stabilized voltage source

Figure 4 shows a set for electropolishing the wire. Before electropolishing, the wire underwent degreasing in a solution composed of: NaOH - 5g, Na_2CO_3 - 25g, $Na_3PO_4 \cdot 12H_2O$ -25g. The temperature of the solution amounted to 75°C, and the time of the degreasing - 4 minutes. The process of wire electropolishing was carried on in a 65% water salution of orthophosphoric acid /H_3PO_4/ at the temperature of 20°C. The electropolished wire was connected with the positive pole of the source, the voltage amounted to 0,8 V, and the current during the polishing of the copper wire, 0.5 mm in diameter and 90 mm long, amounted to 0.4 A. The time of electropolishing was 30 minutes.

RESULTS

Figure 5 shows the U_e voltage of occurrence of the 1 μA electron emission current, according to the diameter of the copper wire. The surface of the wire was only washed with alcohol. This figure presents the values of the arithmetic mean, calculated for fifteen measuring points as well as the standard deviation.

Figure 6 presents the U_e voltage of occurrence of the electron emission current from the wire, according to the H spacing between the electrodes, for a wire 0.15 mm in diameter and electrodes 22 mm in diameter which have been selected as an example. Figure 7 presents, for the same wire and the same electrodes the values of the arithmetic mean of the U_e voltage as well as standard deviations, according to the H spacing of the electrodes. Figure 8 presents in the common coordinate system the characteristics of U_e voltage, in the function of the H electrode spacing, for five diameters of the wire and for the 34 mm diameter of the electrodes. Figures 9 and 10 show analogical characteristics for the 22 and 14 mm diameters of electrodes. For small spacing of electrodes, equal to 0 - 25 mm, the electron field emission from the wire may not occur , whereas the emission current or breakdown occurs between the disk electrodes and the cylindrical

- improvement of the wire surface roughness, obtained by electropolishing.

EXPERIMENT

Samples

A copper wire 0.07, 0.15, 0.30, and 0.90 mm in diameter was used for the investigations. The wire was washed in alcohol or electropolished. The electrodes, made of electropolished copper, had the shape of disk 14, 22 and 34 mm in diameter.

Measuring systems

Figure 1 shows the investigated object. All the investigations were carried out at alternating voltage of 50 Hz, in the vacuum of the order of 10^{-4} Pa. The current of electron field emission was measured between the wire (1) and the cylindrical electrode(3), using the method of the high voltage unbalanced bridge, shown in Figure 2. Figure 3 shows the oscillogram of the emission current. Emission of electrons from the wire occurs only in the negative half-period of the voltage.

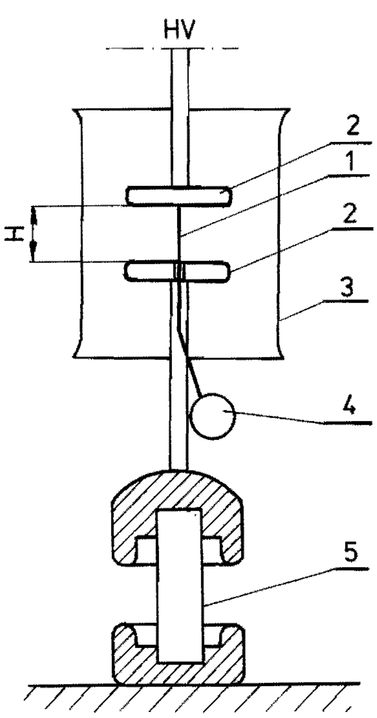

Fig.1. Electrode arrangement
1-investigated wire,
2-screening electrodes,
3-cylindrical electrode,
4-load sphere, 5-insulator

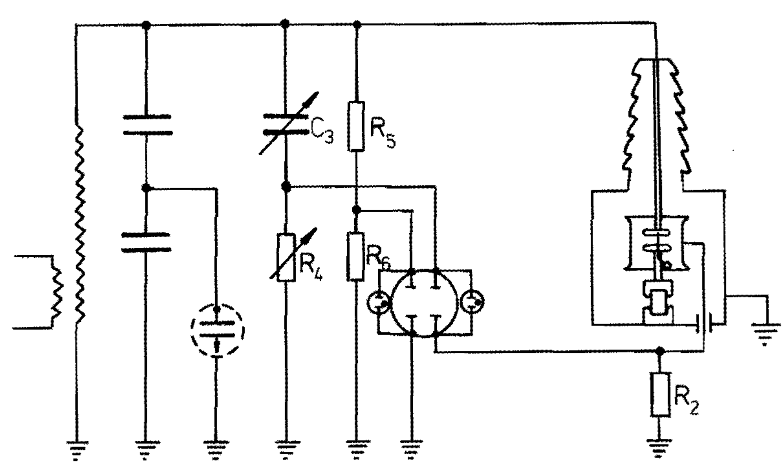

Fig.2. High voltage bridge for measuring the emission current

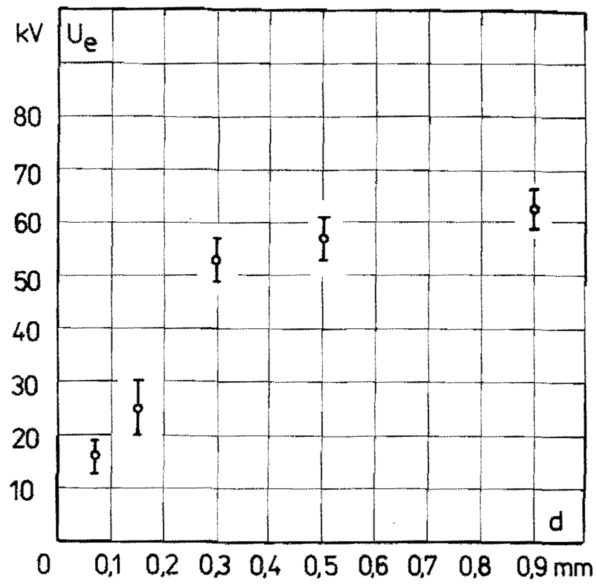

Fig.5. Voltage U_e where the electron emission current equals 1 μA for various diameter of the copper wire

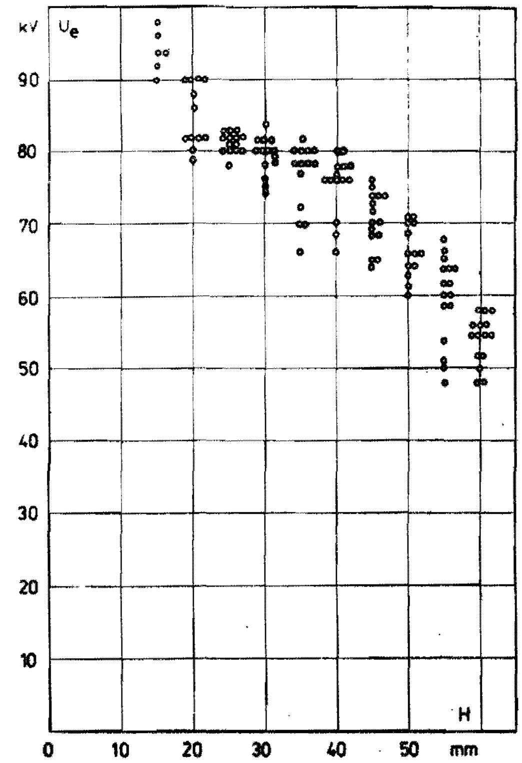

Fig.6. Voltage U_e where the electron emission current equals 1 μA, according to the spacing between the electrodes for a wire of 0.30 mm diameter and for the electrodes of 22 mm in diameter

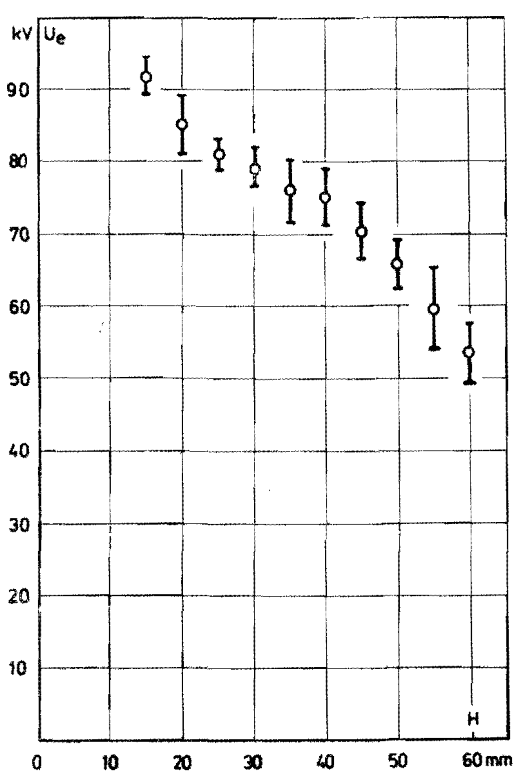

Fig.7. The values of the arithmetic mean of the voltage U_e and standard deviations, according to the spacing H of the electrodes. Wire diameter 0.30 mm electrodes diameter 22 mm

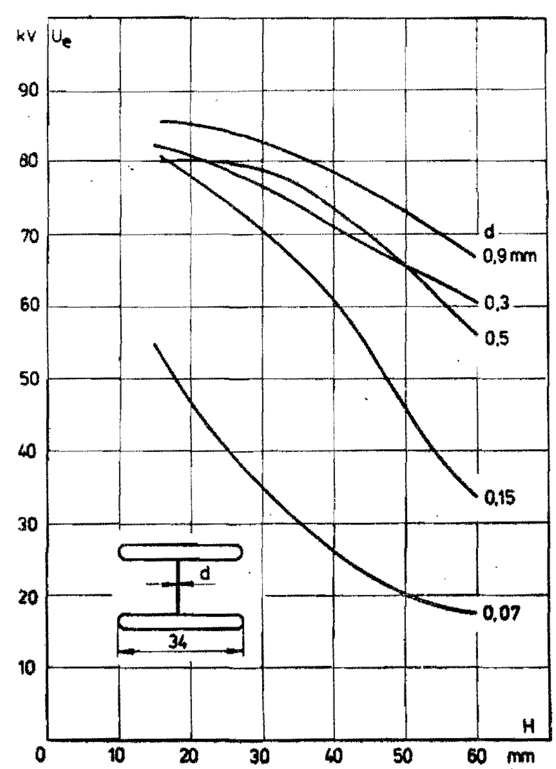

Fig.8. Voltage U_e where the electron emission current equals 1 μA, as a function of the electrode spacing H for five diameters of the wire and for the electrode diameter 34 mm

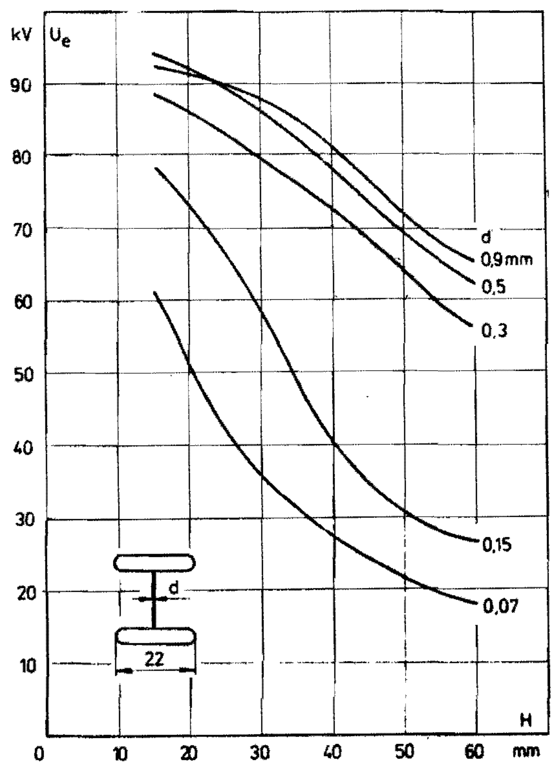

Fig.9. **Voltage U_e where the electron emission current equals 1 μA,** as a function of the electrode spacing H for five diameters of the wire and for the electrode diameter 22 mm

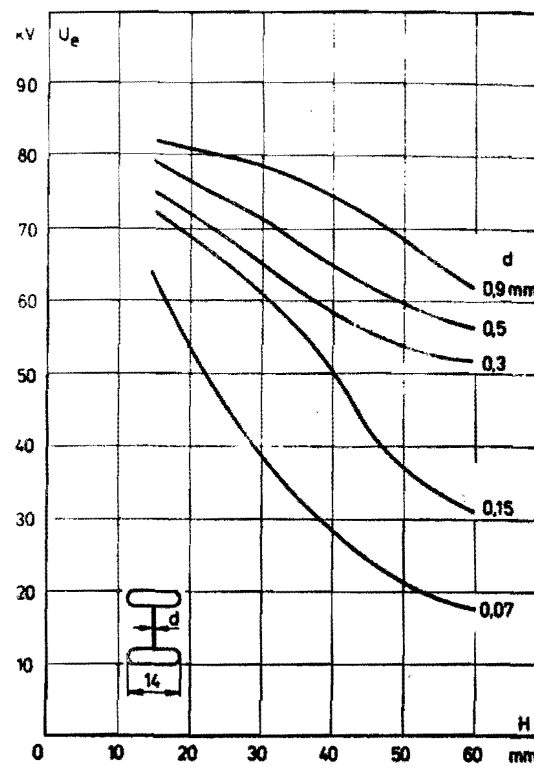

Fig.10. Voltage U_e where the electron emission current equals 1 μA, as a function of the electrode spacing H for five diameters of the wire and for the electrode diameter 14 mm

electrode.

It results from the analysis of characteristics in Figures 8, 9 and 10 that the approaching of electrodes causes a distinct limitation of the field emission phenomenon and increase in the U_e voltage of the occurrence of the electron emission current and this should be associated with the phenomenon of wire screening by electrodes. In the case of electrodes of small diameter (ϕ = 14 mm), the effect of wire screening is less.

In the second part of the experiment, the influence of the technology of wire electropolishing on the phenomenon of the electron field emission from the surface of the wire was investigated. After electropolishing, smoothness of the wire surface increased and the change of the diameter was 0.05 mm. It was found that the U_e voltage of occurrence of the electron emission current from the surface of the electropolished wires is of about 25% higher in comparison with nonelectropolished wires.

CONCLUSION

1. The undesired phenomenon of electron field emission, from a wire in a high voltage vacuum fuse, can be reduced or eliminated by wire screening as well as by electropolishing its surface.

2. The effect of wire screening can be obtained in a simple way by applying electrodes of the shape of disks to its ends. The effect of screening is the greater the bigger the diameter of the electrodes is and the smaller their spacing is.

3. On applying electropolishing of the wire, an increase in about 25% in the voltage of occurrence of the electron field emission current from the surface of the wire was obtained.

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