ARCING PHENOMENA IN A TYPE OF LOW VOLTAGE FULL RANGE FUSES

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Abstract

In this paper, the authors give out a kind of full range fuse applying to the low voltage power distribution system, the element structure of which is made of silver or copper metal combined with M-spots and gasing material. The authors explain the experimental results and obtain the main experimental conclusion from the test samples as follows: The element can improve the rupture of low overload currents and high rated breaking current.

1. INTRODUCTION

In recent years, a new kind of fuses have been developed in few countries with full range clearing ability, which could be described as " a current limiting fuse, capable of breaking under specified conditions all currents from the rated breaking current down to the lowest overload current that causes melting of the fuse element " (6).

IEC recommendations requires for standard fuses that the shapes of the time current characteristics lie between definite time current values in the overload and short circuit range, the temperature rise should be below the specified values and the breaking test should finished under the requirements. So all the experiments are according to these recommendations.

2. CONSTRUCTION OF FUSE ELEMENT AND TEST CIRCUIT

The main parts of the fuse element are (shown in Figure 1):
(a) Basic element which is a notched strip is made of silver or copper metal;
(b) M-spots are used to be better off the breaking performance of low overload currents, which are located at the necks of fuse element;
(c) Covered medium (gasing materials) is made of PTEE (polufluortetraethylene) to quench arc and to advance the dielectric recovery strength by producing gases. It is belted on the basic element.

Figure 2 shows the principle of the breaking test circuit with low overload currents. The turn-over time from the subsidary circuit to the main circuit is less than 0.08 second by our automaticall controlled device. The voltage of subsidary circuit is about 10V and the voltage of main circuit is 550V.

The main measuring instruments for low overload breaking test are as follows:
(a) A time counter records the prearcing time and the arcing time;
(b) A tape memory recorder and a light-ray oscillograph both are used measuring the fuse arc voltage and current with low overload.

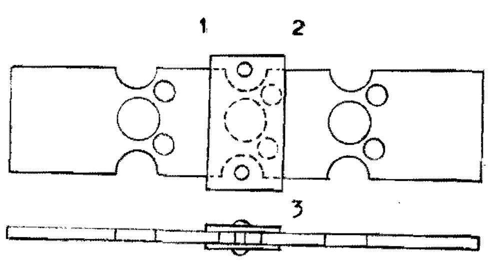

Figure 1. Fuse element

1——M-spots 2——Covered medium
3——Bolt

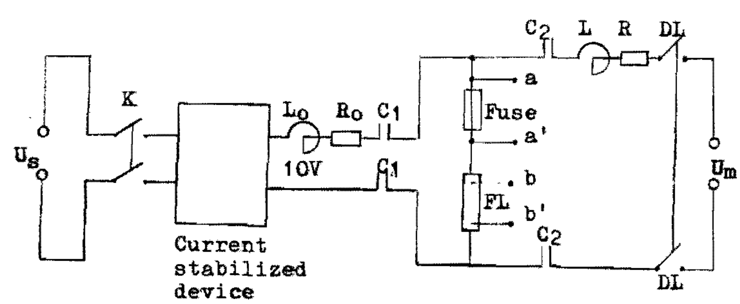

Figure 2. The principle of the breaking test circuit with low overload currents

U_s=220V U_m=550V FL——Shunt C_1,C_2——Contacters

3. EXPERIMENTAL PHENOMENA

3.1 LOW OVERLOAD CURRENT REGION

If it is not specified, the low overload current means the current less than $3I_n$ and more than $1.25I_n$. Low overload current breaking tests prove that the fuse element sometimes multiple reignition take place (arcing, recovery and reignition for a few semiwaves) then clearing.

For copper fuses, if I_p is less than $1.6I_n$, the multiple reignition would occru. The typical curve of this phenomena is shown in Figure 3. Fulgurites are comparatively regular and have black colour near M-spots, red colour among them, white colour in the other region and also clear grains of quartz sand. M-spots in the neck of constrictions except the middle constriction have the melting traces and spots. The total length of arc lumen is not longer than the diameter of siddle holes in the fuse element in normal cases.

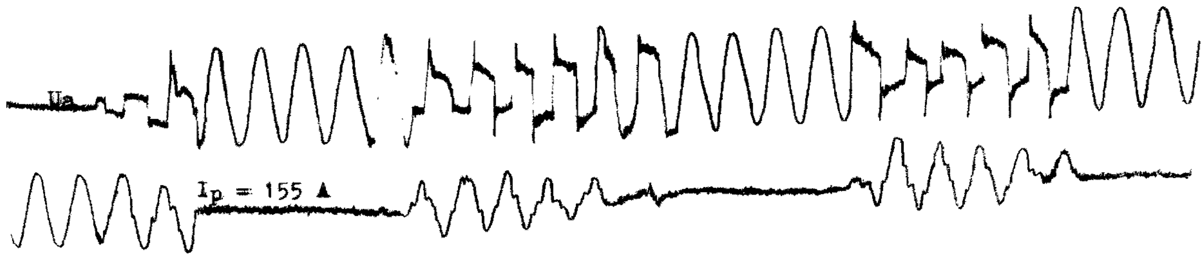

Figure 3. The typical curve of low overload current breaking test (for copper element)

The permanent high frequency oscillation phenomena are observed in the measurement of arc voltage which is flat on the average in the initial 1-2 ms. Near the zero current region, the voltage frequency is about 1 kHz and then the voltage frequency is higher than 1 kHz.

For silver fuses, no multiple reignition is found, under the same conditions as copper fuse test circuit parameters, the arc gap is shorter and the total arcing time is much smaller, the remains of covered materials are more than that of copper. M-spots on the two sides are seen to have subtle melting traces.

3.2 SHORT CIRCUIT CURRENT REGION

For sort circuit current test up to 50kA(r.m.s.) at 550V. Insulation resistances of copper fuses are above 100 KΩ, sometimes up to 2.5 MΩ and insulation resistances of silver fuses are above 100 KΩ too which are satisfied with the IEC recommendations (1). The typical curves of short circuit test with 50kA (cos=0.15) are shown in Figure 4.

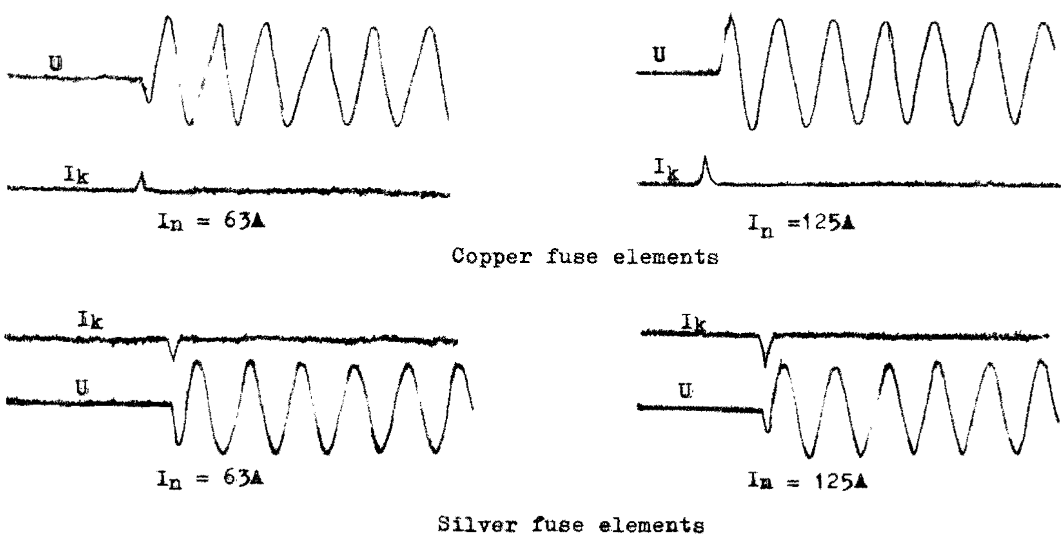

Figure 4. The typical curves of short circuit test

4. M-EFFECT AND G.Q.A. (THE GAS QUENCHING ARC PRINCIPLE)

In recent years, some scholars investigated the fusing and aging behavior of fuse elements with M-spots (9) (10) to indicate the two different patterns of fusing. In our tests, it is observed that the melted tin flows forward to the element neck, until the melted tin reaches to the element neck, the basic element begins to dissolute to the liquid state and it develops more quickly. The dissolution and the penetration are alternatively produced. It makes the electric conductivity and the thermal conductivity of element decreasing. While the surfacial force on the liquid phase can't keep the ballance. The element necks are vapourized and produce arc suddenly. These process may be explained by Figure 5. Figure 5(A) shows the liquid tin contacts the surface of the basic element. Figure 5(B) shows the two materials(tin and copper) occures dissolution and penetration. Figure 5(C) shows the two materials completely dissolution and penetration. Figure 5(D) shows the liquid state of the two materials starts to occur arc. If the quantity of tin M-spots are so small and thin, the liquified time should be delay that means M-spots effect needs to a long time.

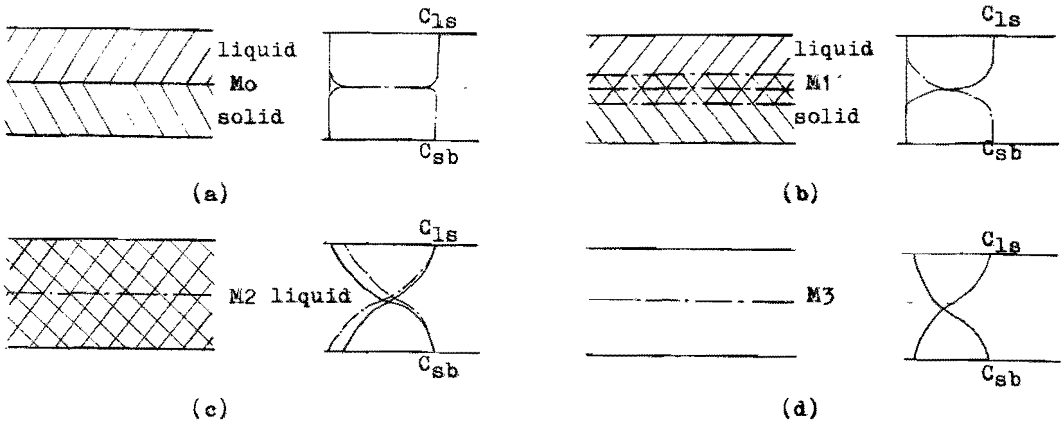

Figure 5. The penetration process of M-effect

The covered material can produce gas and change the dissipated heat state of the fuse-elements, when the elements change into liquid state, the gas promote it to vapourize. The electric conductance becomes insulation state and higher dielectric recovery strenth may be established. What is more, a lot of energy may be consumed by quartz sand to against arc reignition. In this sense, the producing gas is a well condition to quency arc.

As for short circuit current, the discomposition of PTFE is very rapid, according to the theory of high polymer chemistry, when PTFE discomposed, its main products are monomer($\geqslant 95\%$) and a little gaseous hydrogem fluoride. F(fluorine) has the highest electronic attaching ability. The products can attach electrons, decreasing the conductance and promoting the establishment of the dielectric recovery strenth.

5. DISCUSSION

5.1 GENERAL ANALYSIS

The differences of arc phenomena between copper fuses and silver fuses existed, the main reason of which is considered that, in breaking low overload current, during the period of copper fuse rupture, more metal vapour is produced in lumen area, there are more electric conductive particles, this may occur the thermal breakdown sometimes, until the column is cooled enough.Meanwhile more quantity of M-spots materials flow into the column or the lumen area, thus the multiple reignition is easy to occur. For the silver element, by the end of reignition that is kept continuously arcing for several ten ms, because of less metal vapour and column cooling, gas quenching arc, attachment of electrons, enough dielectric recovery strength had been formed, so the multiple reignition couldn't show up. From the viewpoint of energy, it followed that in this circumanstance, there are not enough input energy to maintain the continuous arc so arc put off, and larger gaps eventually created the good conditions for higher dielectric strength.

5.2 FULGURITES

With low overload, the formation of fulgurites depends on mainly the arc energy and the temperature fields of elements, so silver fuses and copper fuses have small fulgurites, but the fulgurites of silver fuses are smaller than those of copper fuses.

Fulgurites of copper fuses after short circuit currents are statistically classified into two kinds: Flat type and tip type.

Flat type hadn't obvious climaxes, the current density $J_1 < J_I$ and $J_2 < J_{Ic}$.

Tip type had striking climaxes, the current density $J_1 > J_I$ and $J_2 > J_{Ic}$.

These two values J_I and J_{Ic} are taken as the critical values of flat type and tip type, $J_I = 4.5 - 5.6 \times 10^6$ $A.cm^{-2}$ from the prospective short current and $J_{Ic} = 1.6\text{-}2.25 \times 10^6$ $A.cm^{-2}$ from the cutoff current.

The primary conclusion is that the copper fuses would be suitable for make of one, two and three fuse elements.

Figure 6. shows the typical photograph of fuse fulgurite after 80A low overload current test.
Figure 7. shows the typical photograph of fuse fulgurite after 50kA short circuit current test.

(80A low overload current test)

Figure 6. The typical photograph of fuse fulgurite.

(50kA short circuit current test)

Figure 7. The typical photograph of fuse fulgurite

6. SUMMARY

(a) The fuse elements with M-spots and covered gasing materials (PTFE) can successfully break low overload current;

(b) In breaking low overload currents, arcing will be multiple reignitions for copper fuses and single reignition for silver fuses;

(c) General description is given about M-effect and G.Q.A.

7. ACKNOWLEDGEMENT

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8. REFERENCES

(1) IEC Publication 269: Low voltage Fuses.

(2) Mikulencky H.W.: Current-limiting fuses with full-range clearing ability. IEEE Trans. on Power Apparatus and System Vol. PAS-84, No12, pp 1107-1116, Dec., 1965

(3) Holec. Corp. : The product sample introduction of h.v. full-range fuses.

(4) P. Rosen: 'Full-range-fusing' —— a new concept in system protection, Electric Review, 213 No4 July, 1983.

(5) Ofte A. and Rondeel W.: Test procedure and arcing phenomena in h.v. fuselinks near the minimum breaking current. Trondheim. International Conference on Electric Fuses and their Applications. 13-15 June, 1984.

(6) Lipski T.: Lectures on Electric Fuses. Xi'an, China. Sept. 1983.

(7) Van der Scheer D. and Reith H.F.J.: High voltage current-limiting fuselinks capable of breaking all currents that cause melting of the fuse element. Trondheim, Int. Conference on Electric Fuses and Their Applications. 13-15 June, 1984.