NEW RESULTS ON THE POST-ARC FULGURITE RESISTANCE OF H.B.C. FUSES

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Abstract: The major new results obtained in the paper are dealing with the share of particular parts of the post-arc fulgurite in the total fulgurite resistance. In the case of Cu-elements the fulgurite is a sum of nearly equally rising in time of swell resistance and resistance after burn-backed fuse-element shoulders. Meanwhile the Ag fulgurite post-arc resistance increase is done mainly by the rise of the swell resistance.

1 Introduction

The importance of the post-arc fulgurite resistance and dielectric withstand of h.b.c. fuses was already underlined in [1, 2]. Late arc reignitions in such fuses is a problem the manufacturers are dealt with because of the eventual fuse explosions. In our previous paper [1] already a number of the preliminary results on post-arc resistance of fuses in question are shown but they are not satisfactory in view of that resistance physical and mathematical modelling. The extension of investigations described below makes possible to elaborate such modelling which is in term presented in the paper [3] submitted to this ICEFA. Still another aim of this report is to get, at least partly, an answer the question: which part of the post-arc fulgurite resistance is responsible for the recovery voltage withstand. The last question, posed in [4], is also important for fuse designers. They want to know whether responsible is the part arising after constriction exploding or the part after fuse-element burn-back. Unfortunately we are not yet in the position to elight above questions analytically. That's why this report is based on an experimental approach only.

2 Tests

The tests were performed at prospective short-circuit current ab. 3.1 kA (RMS), p.f.= 0.27, source 50 Hz voltage ab. 400, 500 and 700 V using circuitry shown in Fig 1. Closing angle was between 0 and 20°el after

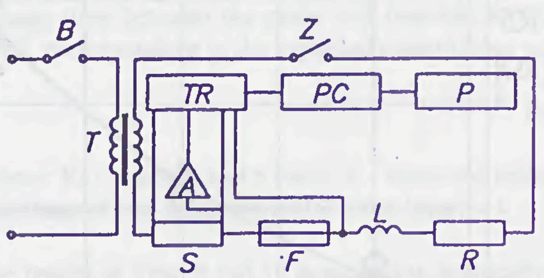

Fig.1 Test circuit.
B - master circuit-breaker, Z - making switch, T - transformer, S - shunt, F - fuse-link model, L - inductance, R - resistor, A - amplifier, TR - transient recorder, PC - personal computer, P - printer

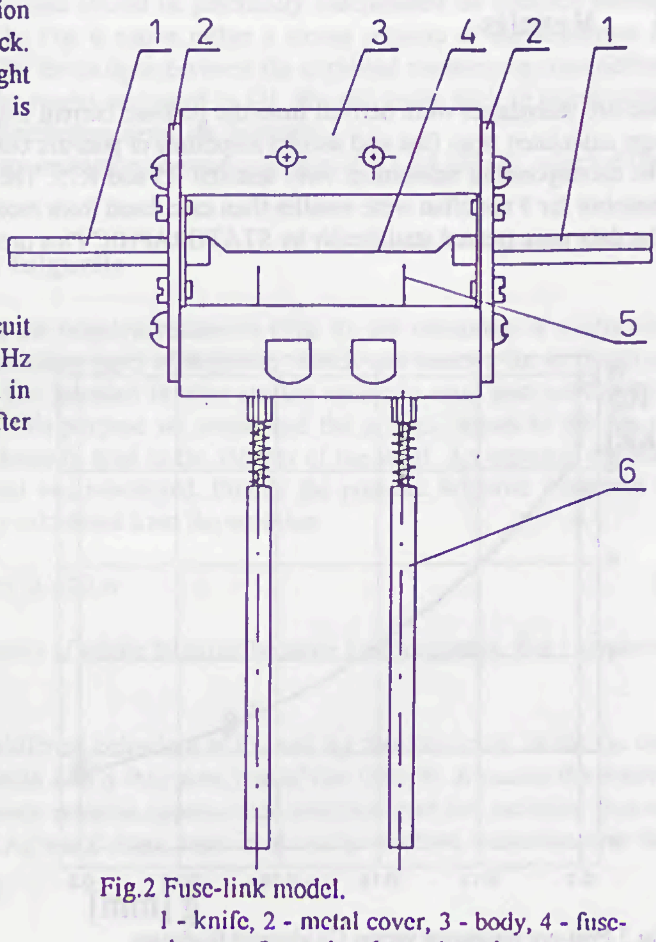

Fig.2 Fuse-link model.
1 - knife, 2 - metal cover, 3 - body, 4 - fuse-element, 5 - probe, 6 - probe grip

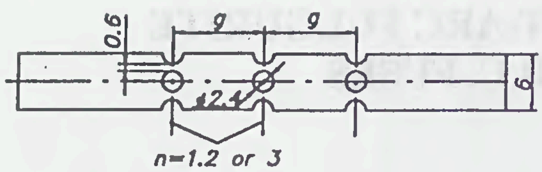

Fig.3 Fuse-element. n - number of constrictions

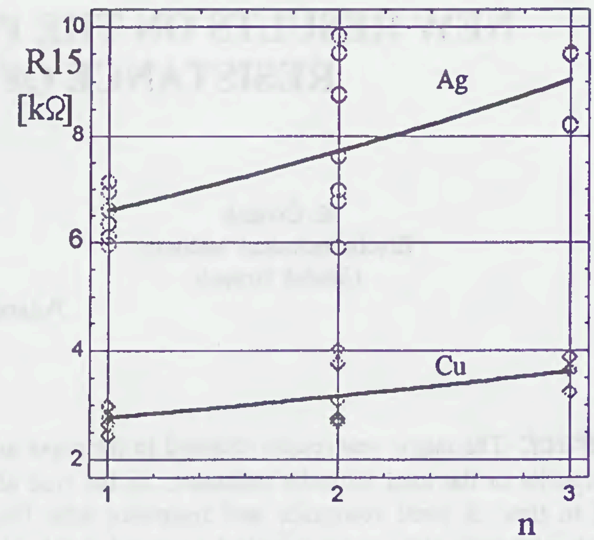

Fig.4 Post-arc resistance versus number of constriction. Source voltage 550 V

source voltage zero. After every shot this voltage was kept across the fuse by 10 s. The post-arc current was monitored continuously by a transient recorder over 0.5s after forced bringing the cut-of current to zero. Small, in comparison with test current, post arc-currents were recorded using a dc amplifier placed close to the shunt to avoid undesirable interferences. Moreover, the voltage between the fuse-terminals and on the special probes inserted into the fuse-link body as well as the short-circuit current were also recorded.

Made of textolite the fuse-link body (Fig. 2) was composed from two parts. One of them, namely the cover, in Fig. 2 is removed. It made easier the fuse-element 4 to place in a correct position and to adjust the probes 5 (Fig. 2). The probes gave voltage signals needed to monitor the post-arc resistance of characteristic parts of the arising fulgurite. The arc-chamber volume of fuse-link was equal to the volume of size 1 industrial DIN fuse-link. A standard quartz-filler of granularity 0.12 ÷ 0.43 mm packed by a standard procedure was used. Cu fuse-elements (Fig. 3) were of 1, 2 and 3 rows of constrictions, made of 0.1, 0.17 and 0.2 mm thick strips, while Ag fuse-elements of only 0.17 mm. It was decided that one Ag strip thickness is sufficient for a comparison with the Cu strip results. The constriction ratio always was 5. The weldings joined the fuse-element to the link-terminals.

3 Results

Post-arc resistances were derived from the post-arc current amplitudes and recovery voltage. Most of the resistances were calculated from first and second amplitude of post-arc current, i.e. 5 and 15 ms after recovery voltage first zero. The corresponding resistances were denoted R5 and R15. The R15 magnitudes seems fit better to analyses because these but for 5 ms often were smaller than calculated from recorded profile regression model.
The data were treated statistically by STATGRAPHIC Plus program.

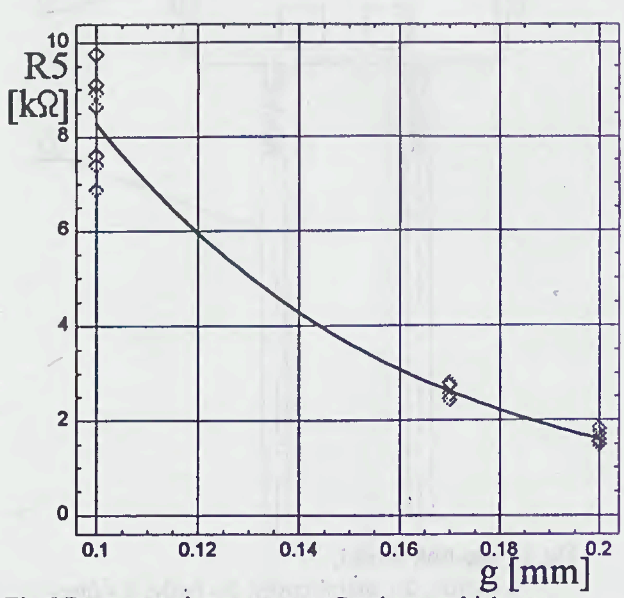

Fig.5 Post-arc resistance versus Cu element thickness Source voltage 550 V

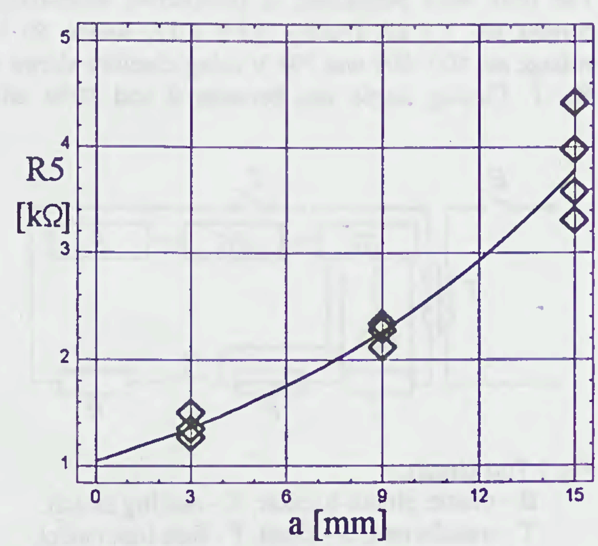

Fig.6 Post-arc resistance versus distance a between the constrictions. Cu fuse-element 0.2 mm thickness, n=3, source voltage 400 V

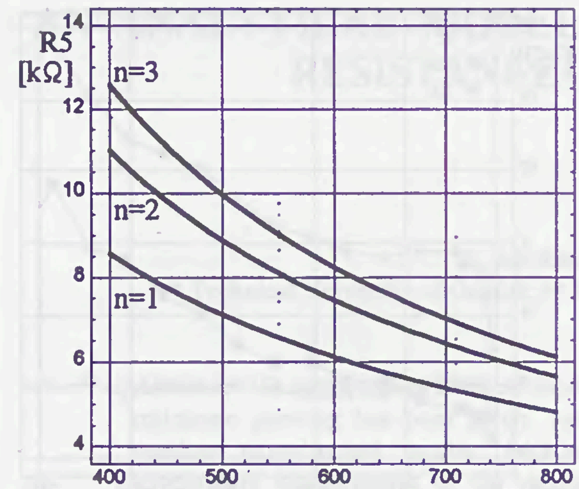

Fig.7 Post-arc resistance versus source voltage. Cu fuse-element 0.1 mm thickness, n - number of constriction

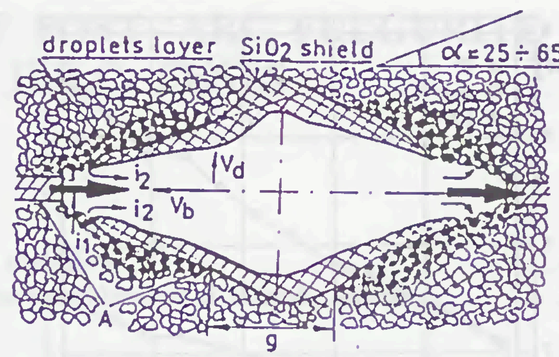

Fig.8 Image of the arc: i_1 - main current path, i_2 - partial current path , v_b - burn-back velocity, v_d - droplets velocity, α - angle between droplets layers and axis, g - recovery withstand gap between droplets layers which in fact is the gap after explosions, A - points of a good galvanic connection [4]

3.1 Post-arc resistance

R15 values as related of the constriction row number n (Fig. 4) by constant strip thickness 0.17 mm show the essential influence of the element-material. In the Ag case the fulgurite resistance in question is ab. 2.5 times higher than that of fulgurite resistance after Cu-elements. Greater the number n greater the post-arc resistance. This increase in some way relates to the weight of fulgurite, but the relation is not so distinct as compares with the influence of the element thickness (Fig. 5). For instance, the fulgurite weight ratio is ab. 1.7 for thicknesses 0.2 mm and 0.1 mm and post-arc resistance ratio is ab. 0.25.

The profiles in Fig. 6 do suggest, that the post-arc resistance is not concentrated only in places after exploded constrictions. If it would be the case the port-arc resistance should be practically independent on distance between the constrictions. In contradiction to last statement the Fig. 6 shows rather a strong relation of the resistance on distance g. The conclusion is that the dispersed metallic drops layer between the exploded consecutive constrictions is not so much current carrying as it outcomes from the model suggested in [4]. We will come back to this question once more speaking below about recorded resistance distribution along the fulgurite.

Fig. 7 demonstrates more precise relation of the post-arc resistance on source voltage at 3.1 kA (RMS), which differs from nearly linear at 50 kA (RMS) [1].

3.2 Post-arc resistance distribution along fulgurite

One can discern at least two important components of the fulgurite resistance (Fig. 8): the resistance of swells after exploded constriction (Rs) and the resistance of outstanding parts of fulgurite, which can contain lot of dispersed metal drops in the sand usually in shape of a layer. The question is what are the shares in total post-arc fulgurite resistance of mentioned individual components. For this purpose we introduced the probes, shown in the Fig. 2, positioned near the expected ends of dispersed metal drops in sand in the vicinity of the swell. An expected dynamic voltage drop between the probe and fuse-link terminal was monitored. Finally the post-arc fulgurite resistance of swell corresponding to the exploded constrictions was calculated from the equation:

$$Rs = R - 2Rm \tag{1}$$

where: Rs - resistance of a swell, R - measured resistance of whole fulgurite between fuse-terminals, Rm - measured resistance of one dispersed metal drops layer.

The results in Figs. 9 and 10 demonstrate drastically different behaviour of Cu and Ag fuse-elements. In the Cu case both resistances Rs and Rm are increasing in time within nearly this same rate of rise (Fig. 9). It means the relative share of both resistances in the total fulgurite resistance remains approximate constant over the recorded post-arc period of ab. 0.5 s. On the other hand, the dispersed Ag metal drops layer is of nearly constant resistance over that period (Fig. 10).

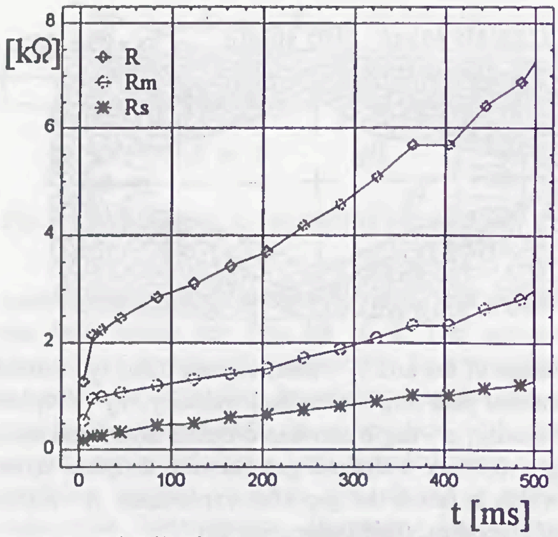

Fig. 9 Distribution of post-arc resistance along different parts of fulgurite of Cu element. R - post-arc resistance of whole fulgurite, Rm - resistance of one metal layer part, Rs - resistance of swell

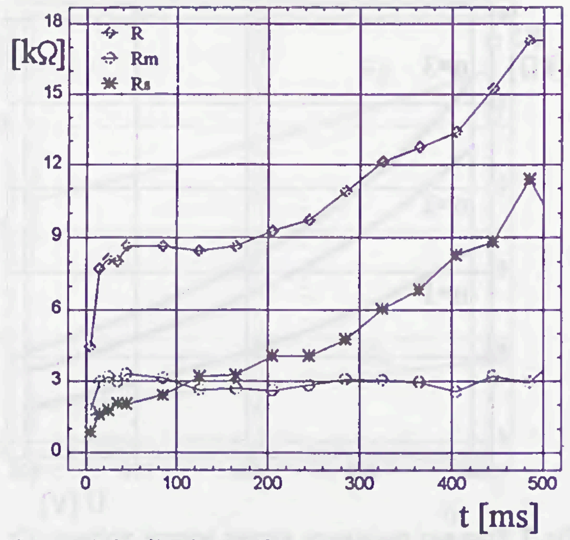

Fig.10 Distribution of post-arc resistance along different parts of fulgurite of Ag element. R - post-arc resistance of whole fulgurite, Rm - resistance of one metal layer part, Rs - resistance of swell

So the post-arc fulgurite resistance increase in the case of Cu-elements is due to nearly equal rise of both Rs and Rm resistances. Meanwhile for Ag-elements the post-arc fulgurite resistance increase is done mainly by the rise of the swell resistance.

4 Conclusions

- The well known priority of Ag fuse-element above Cu one for h.b.c. fuse also from the point of view of the higher post-arc fulgurite resistance has been confirmed;
- Weight of fulgurite is correlated with the thickness of the fuse-element and with the post-arc resistance. Thinner the fuse-element strip higher the resistance e.g., by factor 4.
- Also at 3.1 kA (RMS), as it was already at 50 kA (RMS), the fulgurite resistance shows a strong relation on the source voltage
- Individual parts of a fulgurite after Cu and Ag strip participate in the increase of the whole fulgurite resistance in different ways. In the case of a Cu-element the increase is due to nearly equal rise in time of resistances of the swells after exploded constrictions and of the dispersed metal drops layer. But for an Ag-element the increase is mainly due to rise of the swell resistances, whereas the resistance of a dispersed metal drops layer is nearly constant over the whole time 0.5 s.

5. References

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