Search for new extinguishing media for LV fuses

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There are described the results of a search for new extinguishing media for LV fuses, especially focused to lowering the Joule integral $I^2 . dt$.

1. Introduction

The aim of the research was the discovering of new extinguishing media for LV fuses, which would be minimally equivalent with a quartz sand, but preferably with a lower value of Joule integral $I^2 . dt$.

The possibility of exploiting some waste materials was taken in account at choice of tested extinguishing media, but first of all, this chice was directed to verify the following hypotheses for improved behaviour of fuses:

a/ the presence of an electronegative compound

b/ the pressure rise inside of the fuse-link caused by chemical decomposition or by loss of crystal water

c/ the pressure rise in the immediate vicinity of the melting-element
ca/ by forming an unpenetrable layer on the surface of the melting element
cb/ by reinforcement of extinguisher /in form of a porous filler/.

According to Bron [1] , the pressure rise causes the lowering of ionisation rate and the rise of thermal conductivity, too. The result is in both cases the rise of arc-voltage gradient and thus the increase of arc instability.

52 kinds of extinguishing media were investigated, see tab. 1 and 2.

2. Test method

Individual extinguishing media were tested in a fuse, all other parts of which were taken from a factory made fuse. The reason was not only the easy availability of these parts but especially the use of a already proved construction, verified by a complete type test. In the beginning of our work we used high-breaking capacity fuses type PH 0, 100 A, gF characteristics, with a copper fuse-element. Later was the work directed to semiconductor fuses, type PC, 100 A, with a silver fuse-element.

The breaking-test were made in accordance with IEC 269-1, /first edition 1968/ and IEC 269-4 /first edition 1974/ at test current I_2, thus with the maximum arc energy. Because some of tested extinguishing media were of organic nature, the recovery voltage was maintained for 5 minutes at all samples tested.

In the first line, the acceptability of test results was evaluated in accordance with IEC Publication 269, namely

- nonpermissible overvoltage

- no externam effects /permanent arcing, flashover or daugerous ejection of flames/
- no desintegration or deformation of replaceable fuse link, which vould prevent its taking off in one piece
- allready mentioned effects shall not occur even in the period of recovery voltage
- insulation resistance shall not be lower thau 100 k

Furthermore, for every extinguishing medium the lowering of Joule integral $J = \int i^2\ dt$ in comparison to standard extinguisher - quartz sand was evaluated.

Because for our tests no meter for $\int i^2 dt$ was available, it was necessary to evaluate this quantity graphicaly from oscillograms by hand, this has been very laborions and time consuming. However, the meter for quantity $E = \int i\ .\ u\ .\ dt$ was at disposal. As can be seen from fig. 1, the correlation betwen J and E exists

$$J = \int i^2 dt = k\ .\ E \qquad /1/$$

Therefore, for evaluation of let-through energy the quantity E was used and thegraphical control of J was made for that extinguishing mediums only, which had the value of E lower than quartz sand.

5 samples were made with each extinguishing medium. The actual number n of tested samples is given in tab. 1 and 2.

Individual extinguishing media were applied with following methods:

- as filling /F/
- as coat /C/ on the melting-element, formed by technology of painting, vacuum evaporation or fluid-bed deposition
- as a pressed-on body on the melting-element /P/ /prism 4 x 14 mm at PC type or 8 x 16 mm at PH type along all active lenght of melting element/.

When using methods C or P, the prepared melting element was placed in a filling of quartz sand of the same grain size /0,3 to 0,4 mm/ as in manufactured fuses.

Characteristics of fuse types used are as follows:

	Type PH	Type PC
active lenght of melting-element 50 mm	50 mm	47 mm
dimensions of melting-element	10 x 0,2 mm	10 x 0,17 mm
number of notches	4	7
cross-section reduction in a notch	12 %	8 %
melting element of	Cu	Ag
volume of fuse-link	21,95 cm^3	19,10 cm^3
cavity dimensions of fuse-link	24 x 15,5 x 59 mm	ø 23...46 mm

3. Results

The results of the search for new extinguishing media are sumarized in table 1 /experiments on high breaking-capacity fuses PH/ and in table 2 /semiconductor fuses PC/. Besides information on composition of individual extinguishing media, about number of tested samples n and about tested hypothesis the tables contain also informations on the method of application of extinguishing medium and about the acceptability of breaking test results according to individual criteria /+ complied with, - not complied/. Effects during tests are characterised by abbreviations: E explosion, D deformation of lids, C cracks in the body of fuse-link, F flames ejection. Unacceptable overvoltage was not observed. Particulars about tests are given in headings of tables.

From tables 1 and 2 can be seen, that a number of extinguishing media is equivalent to quartz sand as regards the breaking capacity at the I_2 current according to IEC 269, the insulation withstand for 5 min after switching and the insulation resistance greater than 100 kΩ . They are either extinguishing media in form of a coat or fillings, which contain at least 80 % of quartz sand. With regard to the fact, that even the melting elements with extinguishing medium in form of a coat were placed in a filling of quartz, good breaking capacity of these media can be attributed from the theoretical point of view to the quartz sand, because the relatively thin coat of extinguisher is rapidly destructed by the arc. This result is in a good agreement also with older, hitherto unpublished experiments, which followed the influence of impurities in quartz sand /in form of metal oxides, especially of ferric and ferrous oxides/ up to concentrations of about 10 %. The influence of impurities on breaking capacity of fuses was not found at that time.

The lowering of quantity E and of Joule integral J as well was found at three sorts of special ceramics NE2,NE3, NE7 only. Their base was quartz sand with the same grain size as in manufactured fuses /0,3 to 0,4 mm/ with organic binder of silicate nature. After thermal treatment the organic component volatilizes and the remaining porous body is of anorganic nature. As however the systematic research of influence of compositin and manufacturing technology of extinguishing media of this type on value of Joule integral J was not made, the boundary value of lowering J in comparison to current fuses with quartz sand is not known.

4. Conclusion

Extinguishing media, which are equivalent to quartz sand, are mixtures with minimal content of quartz sand of 80 %, or coats on melting elements placed in filling of quartz sand. From the economical point of view they are therefore disadvantageous in comparison with pure sand. Extinguishing medium of another chemical composition than SiO_2 was not found.

The lowering of let-through energy /Joule integral can be realited only by use of reinforced porous extinguishing medium on the base of SiO_2 with a binder, which remains after thermal treatment anorganic silicate /"artifical sandstone"/. Boundary value of lowering the Joule integral cannot be determined from existing experiments, but the reached results suggests the way of future work.

From the working hypotheses those of influence of electronegative compounds, of pressure rise by decomposition of chemical compounds or by loss of crystal water and of pressure rise in immediate vicinity of the melting element by means of a layer on it are to be rejected. The influence on lowering the value of Joule integral has the reinforcement of extinguishing medium only /hypothesis ca/.

The mention worth is the failure of Al_2O_3 as extinguisher, not only in calcinated but in crystalic form, too, even when a priori on account of chemical composition and of physical properties at least the equivalence with SiO_2 was expected.

5. References

[1] **Bron O.B.: Arc in switchgear. /in russian/. Gosenergoizdat, Moskva - Leningrad 1954.**

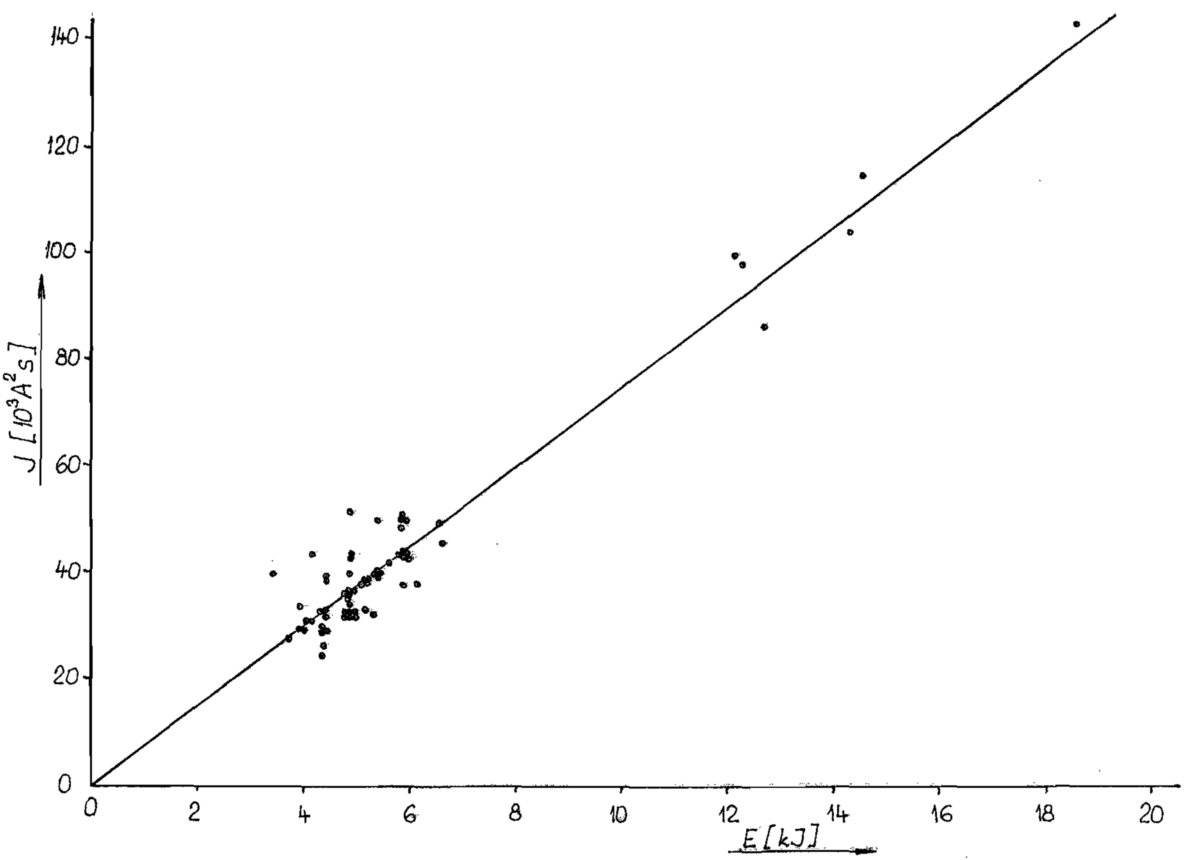

Fig. 1

Tab. 1 Experiments with extinguishing media in high-breaking capacity fuses, type PH 0, 100 A, characteristics gF. No 1 to 11: I_2 = 2700 A, cos phi=0,25. No.12 to 25: I_2 = 2800 A, cos phi = 0,2. All tests at 550 V, 50 Hz. Binder LH 20 on epoxy base

No.	Composition	Hypothesis	Application	Number of samples	Evaluation: breaking capac.	Evaluation: insul. ability	Evaluation: insul. resistance	Evaluation: lowering of $I^2.t$
1	MoS_2, binder PMMA	ca	C	5	-CF	+	+	-
2	PMMA	ca	C	4	+F	+	+	-
3	ground mica 0,25 mm	b	F	5	-F	+	+	-
4	ground mica 0,75 mm	b	F	5	-F	+	+	-
5	carborundum /SiC/ grain 0,5mm		F	5	-E	+	+	-
6	white corund /Al_2O_3/,grain 0,4		F	5	-CD	+	+	-
7	brown corund /Al_2O_3/,grain 0,32		F	5	-E	+	+	-
8	$Al_2O_3.3H_2O$, grain 0,1 mm	b	F	5	-F	+	+	-
9	PTFE, powder	a	F	5	-F	+	+	-
10	MoS_2, binder water glass	ca	C	5	+	+	+	-
11	water glass	ca	C	4	+	+	+	-
12	evaporated PTFE,layer 5 µm	ca	C	5	+	+	+	-
13	evaporated PTFE,layer 10 µm	ca	C	5	+	+	+	-
14	PTFE fluid bed deposited	ca	C	4	+C	+	-	-
15	10% PTFE,10% binder LH 20, 80% SiO_2	a	F	5	+	-E	-	-
16	80% PTFE, 20% binder LH 20	a	F	5	+	-E	-	-
17	10% PTFE, 15% binder LH 20, 75% $Al_2O_3.3H_2O$ /grain 0,1/	a	F	5	+	+	+	-
18	ground mica 0,75 mm	b	F	5	-F	+	+	-
19	$Al_2O_3.3H_2O$, grain 0,1 mm	b	F	5	+	+	-	-
20	20% $Al_2O_3.3H_2O$, grain 0,2 mm, 80% SiO_2	b	F	5	+	+	-	-
21	40% $Al_2O_3.3H_2O$, 60% SiO_2 dtto	b	F	5	+	+	-	-
22	60% $Al_2O_3.3H_2O$, 40% SiO_2 dtto	b	F	4	+	+	-	-
23	80% $Al_2O_3.3H_2O$, 20% SiO_2 dtto	b	F	4	+	+	-	-
24	100% $Al_2O_3.3H_2O$ dtto	b	F	5	+	+	-	-

Tab. 2 Experiments with extinguishing media in semiconductor fuses PC, 100 A.
I_2 = 1800 A, 550 V, 50 Hz, cos phi = 0,2.

No	Composition	Hypothesis	Application	Number of samples	Evaluation			
					breaking capac.	insul. ability	insul. resistance	lowering of $I^2 . t$
25	10% MoS_2, 90% SiO_2	a	F	5	+	+	+	-
26	20% MoS_2, 80% SiO_2	a	F	5	-F	+	+	-
27	5% PTFE, 10% $Al_2O_3.3H_2O$,85%SiO_2	a+b	F	4	+	+	+	-
28	10%PTFE,20%$Al_2O_3.3H_2O$,70% SiO_2	a+b	F	5	-D	+	+	-
29	10%PTFE,60%$Al_2O_3.3H_2O$,30% SiO_2	a+b	F	5	+	+	-	-
30	10% mica 0,75, 90% SiO_2	b	F	5	-E	+	+	-
31	20% Ca SO_4 powder, 80% SiO_2	b	F	5	+	+	+	-
32	50% Ca SO_4 powder, 50% SiO_2	b	F	5	-F	+	+	-
33	80% Ca SO_4 powder, 20% SiO_2	b	F	5	-F	+	+	-
34	10% $Na_2B_4O_7$. 10 H_2O,90% SiO_2	b	F	5	+	+	+	-
35	20% $Na_2B_4O_7$. 10 H_2O,80% SiO_2	b	F	5	+	+	-	-
36	50% $Na_2B_4O_7$. 10 H_2O,50% SiO_2	b	F	4	+	+	-	-
37	5 % H_3BO_3, 95% SiO_2	b	F	5	+	+	+	-
38	10% H_3BO_3, 90% SiO_2	b	F	5	+	+	+	-
39	20% H_3BO_3, 80% SiO_2	b	F	5	+	+	+	-
40	10%PTFE, 8% binder LH20,82%SiO_2	ca	P	5	+	-E	-	-
41	17%PTFE, 8% binder LH20, 75 % Al_2O_3 . $3H_2O$	ca	P	5	+	-E		
42	20% binder LH20, 80% SiO_2	ca	P	5	-D	+	-	-
43	10% binder LH20, 10% mica 0,75 80% SiO_2	ca	P	5	+	-E	-	-
44	10% binder LH20, 10%$Al_2O_3.3H_2O$, 80% SiO_2	ca	P	5	+	-C	-	-
45	special ceramics NE1	cb	P	3	+	+	+	-
46	dtto NE2	cb	P	3	+	+	+	+
47	dtto NE3	cb	P	3	+	+	+	+
48	dtto NE7	cb	P	5	+	+	+	+
49	water glass, coat 1 mm thick	ca	C	5	+	+	+	-
50	PMMA, 0,1 mm thick	ca	C	5	+	+	+	-
51	20% mica, 80% water glass, 0,1 mm thick	ca	C	5	+	+	+	-
52	10% H_3BO_3, 90% PMMA, 0,2 mm thick	ca	C	5	+	+	+	-