BREAKING TESTS OF LOW BREAKING CAPACITY MINIATURE FUSE-LINKS

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1. Lbc and hbc miniature fuse-links

Standard rated breaking capacity for low-breaking capacity miniature fuse-links(lbc MFs), specified in Standard Sheets 2, 3 and 4 of IEC 127-2 and also in Standard Sheets 3 and 4 of IEC 127-3, is 35A or 10 times the rated current whichever is greater at their rated voltage; while Standard Sheets 1 and 2 of IEC 127-3 specify 50 A for the rated current of their lbc MFs.

In any case, the standard breaking capacity of the lbc MF is far lower than the corresponding value of 1,500A for the high-breaking capacity miniature fuse-links(hbc MFs) according to Standard Sheets 1 and 5 of IEC 127-2.

This large difference in breaking capability is attributable to the sand-filling of the hbc MFs. The sand, filled tightly in the fuse-envelope of the hbc MF, causes limitation of the overcurrent in the circuit, often reducing the actual breaking current of the fuse-link far below the prospective overcurrent.

The extent of the current-limitation depends on the ratio of the prospective overcurrent to the rated current of the fuse-link; for the larger ratio the limitation is stronger. Because of this, breaking performance of a hbc MF depends substantially on its rated current.

In the case of lbc MFs, however, no strong current limitation takes place, and the breaking current is essentially equal to the prospective overcurrent which is determined only by the circuit constants. Hence, the breaking performance of a lbc fuse-link depends on the prospective overcurrent but not so much on its rated current as in the case of hbc fuse-links.

2. Arc-energy of lbc MFs

In return for the freedom from the troublesome sand-filling, the glass envelope of the lbc MF is exposed to the intense heat of the arc. On the other hand, its moderate test current doesn't generate that violent and explosive vapourization of the fuse-element which sometimes destroies the envelopes of hbc fuse-links mechanically. Because of these two facts, almost all failures in the breaking tests of lbc MFs are of thermal, rather than mechanical, nature.

Just for this reason, arc-energy measurement during breaking tests of lbc MFs becomes very important for the estimation of their breaking capacity limit.

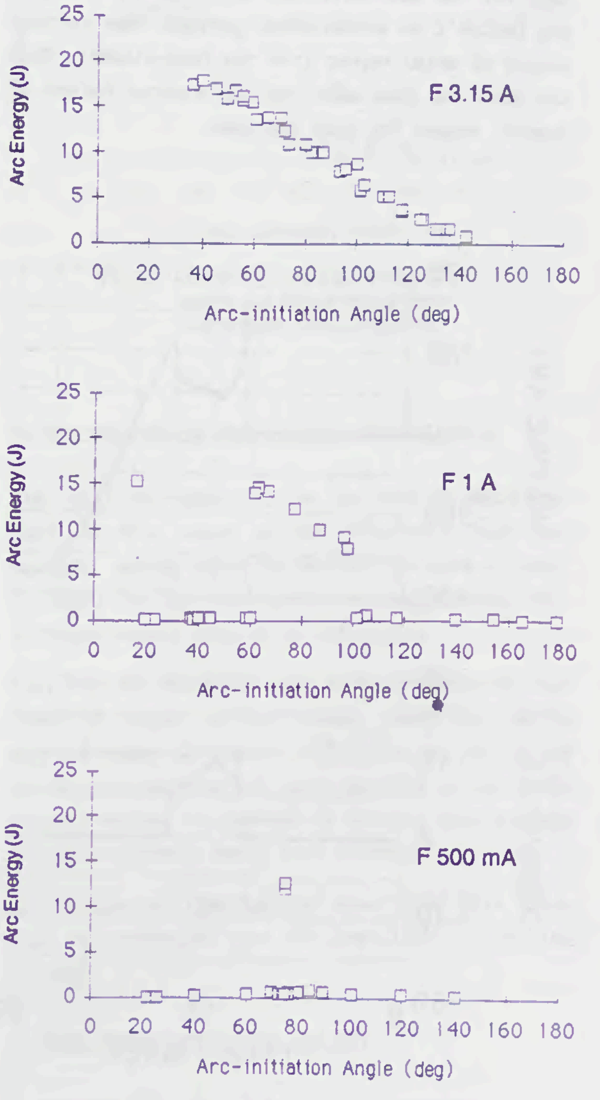


Fig. 1 Test results of 5 x 20 mm fuse-links to IEC 127-2, at 250 V - 35 A (Quick-acting, manufacture A)

3. Arc-energy versus arc-initiation angle

Fig. 1 shows three diagrams for arc-energy in terms of arc-initiation angle on the source voltage wave for 5 x 20 mm quick-acting fuse-links. Current ratings are 3.15, 1 and 0.5A from top, for test current 250V- 35A. All these test pieces were products of a single manufacturer, A.

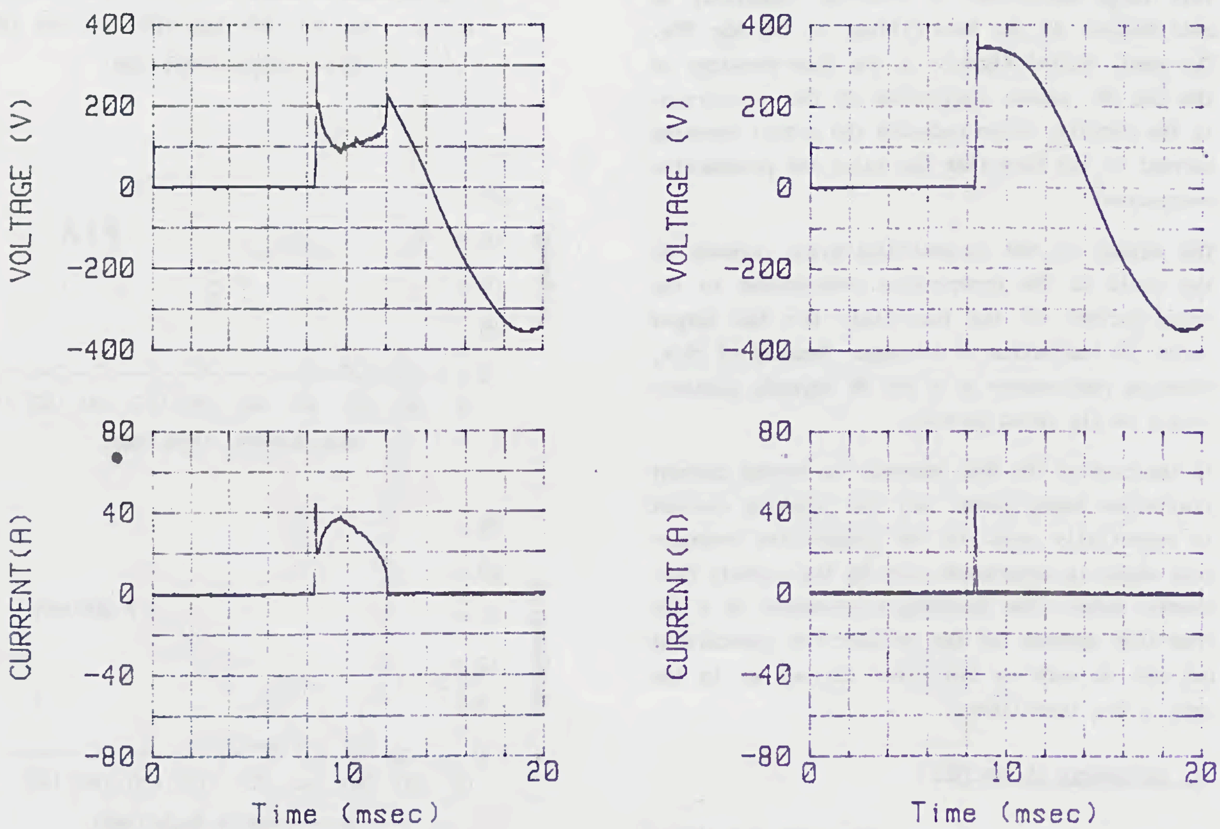
The top diagram shows the arc-energy decreasing almost linearly with the increase in the arc-initiation angle, which implies that in every test arc lasted until the first voltage zero. This diagram is in general agreement with the arc-energy/arc-initiation diagram by H.W. Turner et al[1].

The middle diagram for 1A fuse-links indicates that for the arc-initiation later than 100 degree arc couldn't be established, perhaps, due to poor supply of metal vapour from the fuse-element. This was also the case when the arc started before 60 degree, except for only one case.

For further smaller rated current of 500mA, arc was established only in three of the total 20 tests, at the arc-initiation angle about 75 degree. In all other cases, arc succeeded in starting but failed in establishment. Fig. 2 indicates the two cases, where arc was established (a) and was extinguished (b).

Interesting is the fact that when the arc is established arc-energy of the three kinds of fuse-links is nearly the same for a definite arc-initiation angle. This observation leads us to the conclusion that the fuse-element of a lbc fuse-link is only an arc-starter and that arc-current and energy during the operation of the fuse-link are determined by circuit constants.

Fig. 3 gives, corresponding to Fig. 1, diagrams for lbc time-lag fuse-links of differing ratings of the same size as before but produced by another manufacturer, B. It indicates that for time-lag fuse-links arc can more easily be established than



(a) Arc established

(b) Arc not established

Fig. 2 Arc duration of 500 mA quick-acting fuse-links (Manufacture A) for quick-acting ones but that the general tendency of the arc-energy which increases with decreasing arc-initiation angle is in common to the quick-acting fuse-links.

Fig. 4 strongly supports our view that arc-energy primarily decides failures in breaking tests of lbc MFs. Here, the diagram shows that failures occured only for test current 163A and only for the earlier arc-initiation. In these cases the glass tubes and, often, the end-caps could not withstand the intense heat of the arc. The test pieces were all by manufacturer A.

Fig. 5 indicates test result of 3.15A quick-acting fuse-links, made by manufacturer B, for test current 35A at various test voltages. Also in this case, arc-energy was decisive for the failures of the test.

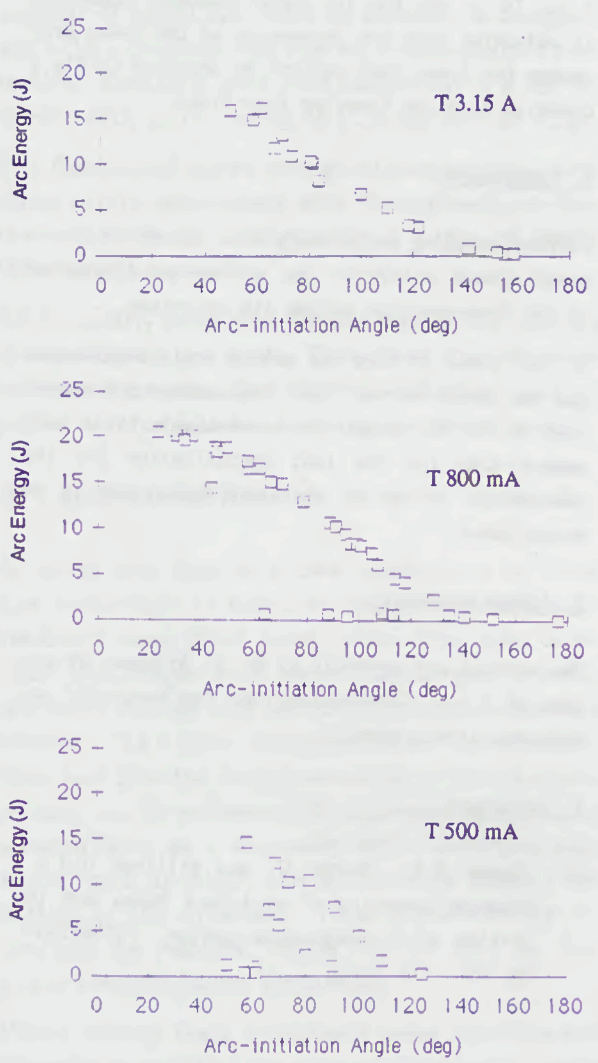


Fig. 3 Test results of 5 x 20 mm fuse-links to IEC 127-2, at 250 V - 35 A (Time-lag, manufacture B)

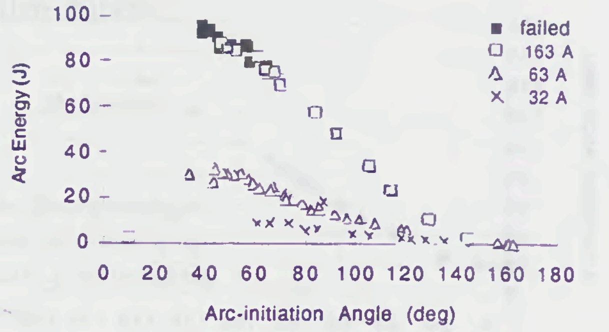


Fig. 4 Arc-energy of 5 x 20 mm quick-acting 6.3 A fuse-links for three test currents (Manufacture A)

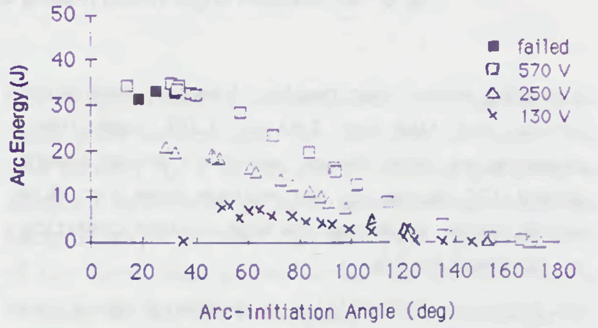


Fig. 5 Arc-energy of 5 x 20 mm quick-acting 3.15 A fuse-links at three test voltages (Manufacture B)

4. Arc-initiation angle versus making angle

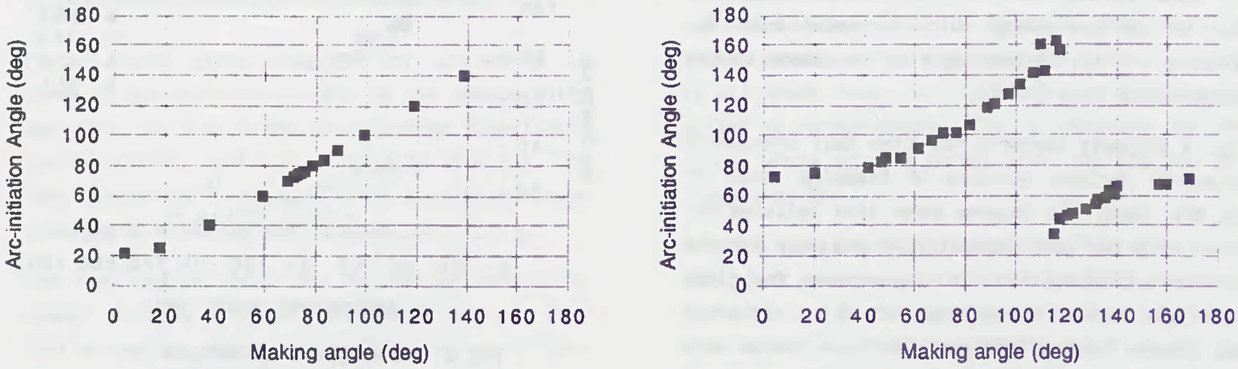
Fig. 6(a) indicates that in the case of small-current lbc MFs, owing to the relatively high test current, making angle on the voltage wave is nearly equal to the arc-initiation angle which distributes widely from 20 to 140 degree.

Fig. 6(b) on the other hand shows the case of fuse links of larger current rating, where arc hardly started before 30 degree. This could be attributed to the slow heating and quick cooling of the fuse-element during its passage of voltage zero because of the relatively small test current.

In the case of time-lag lbc fuse-links this tendency is noticeable even for fuse-links of smaller ratings.

5. Test requirements for lbc MFs

At present IEC 127-1, which deals with general requirements for miniature fuse-links, specifies for all breaking tests of all miniature fuse-links, uniquely, making angle of 30 degree on the voltage wave.



(a) 500 mA (b) 6.3 A

Fig. 6 Arc-initiation angle versus making angle of quick-acting fuse-links (Manufacture A)

According to our test results, however, some quick acting (not time-lag) 2.5A or 3.15A fuse-links, depending on their design, may start arcing always around 150 degree on the voltage wave for this making angle, producing the most lenient condition as suggested by Fig. 1.

Furthermore, if a homogeneous series of quick-acting fuse-links had such a fuse-link as the head and a small fuse-link, say 200mA, as the tail, the test result will be evident before the tests. Thus, the requirement concerning the making angle must needs be re-examined.

IEC 127-1 also requires miniature fuse-links to be tested for currents of approximately 5, 10, 50 and 250 times the rated current not exceeding the rated breaking capacity. The preceding Fig. 4, however, hints that breaking tests for currents lower than the breaking capacity might be useless.

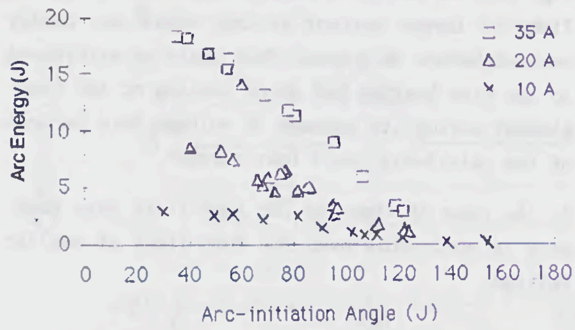


Fig. 7 Arc-energy of 5 x 20 mm time-lag 2A fuse-links for test currents 5In, 10In and the breaking capacity (Manufacture A)

Fig. 7 represents arc-energy of time-lag fuse-links, made by manufacturer A, for test currents 5 In, 10 In and for the rated breaking capacity. It indicates that the phenomenon of the lower arc-energy for lower test current as depicted in Fig.4 prevails also for time-lag fuse-links.

6. Conclusion

Current-breaking performance of a lbc MF is determined almost solely by the arc-energy dissipated in the fuse-envelope during its operation.

In this point of view the making angle requirement and the lower current test requirement now specified in IEC 127-1 must be re-examined. It is necessary also for the test specification for the homogeneous series of miniature fuse-links to be established.

7. Acknowledgement

The authors are grateful to Mr. H. Arikawa, President of S.O.C. Corporation, who has supported and encouraged our research.

8. Reference

[1] Turner H.W., Turner C. and Williams D.J.A., Breaking capacity of miniature fuses and the testing of a homogeneous series, ICEFA/1987, pp 169 - 174