# "ABLATIVE MATERIALS AS A NEW POSSIBILITY FOR THE DESIGN OF MINIATURE FUSES"

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## ABSTRACT

In principle the use of ablative material as an arc-extinguishing medium is not new;they were used before in, for example, circuitbreakers. However their typical properties make them ideal for the design of miniature fuses. In this paper we will give some results of breaking capacity tests and some physical aspects will be discussed. The use of new materials for miniature fuses makes additional tests necessary. A proposal for new test methods will be given.


## 1. INTRODUCTION

IEC-publication 127 requires for miniature high breaking capacity fuses an interrupting ability of 1500A, but in practice also higher interrupting abilities are required, e.g. 5 to 6kA. Moreover, it may be expected that in future a greater demand for such fuses will be there. It is current practice to obtain such a high breaking capacity by using a filler material, normally quartz sand. This sand-filling of fuses however introduces manufacturing-problems and thus increased manufacturing costs. A way to avoid sand-filling of fuses is the use of an ablative material for the fuse body.

## 2. THE POSSIBILITY OF MAKING HBC-FUSES WITHOUT SAND FILLER

From past experience we already knew that it is in principle possible to make HBC-fuses without sand filler [1]. The condition is that the discharge after blowing the fuse element should be enclosed in a hole of relatively small dimensions. Under this condition the behaviour of such a fuse during the arcing period is comparable with those of a sand-filled fuse. Further it has been shown in [1] that blowing a fuse element in a small hole in an epoxy-resin tube gives rise to higher arc-voltages compared with the arc-voltage in a ceramic of equal dimensions. Further it has been demonstrated that the obtained experimental results can be rather well explained theoretically.

The above mentioned condition for the space left to the discharge after blowing the fuse element can be realised in miniature fuses rather easily. Moreover, the relatively moderate requirements with respect to the interrupting capacity of miniature fuses create not too severe conditions regarding pressures arising in the volume where the arc is burning. So, in developing HBC-fuses without sand filler, the most obvious first step is the development of HBC-miniature fuses without sand filler. This is the more so because the sand-filling process is a rather serious complication in an automatic fuse manufacturing process of miniature fuses.

## 3. BENEFITS OF THE USE OF ABLATIVE MATERIALS

Ablative materials have the property that gasses are evolved due to arcing. This means that rather large energies are required for desintegration of the inner layer of the fuse body material. Moreover the desintegration products of an ablative material assist in quenching the arc.

A lot of common polymeric materials are known which have more or less good arc-interrupting and gas-evolving characteristics [2]. Polymeric materials also have the advantage that they are insulating materials and they can easily be moulded. The moulding process allows for a greater freedom in shaping the fuse body, meaning that also other designs are possible to make these fuse types better suitable for automatic production technologies. Making use of ablative materials for fuses, however, requires special plastic materials which should withstand relatively high temperatures and which should have sufficient mechanical strength to be able to withstand the relatively high pressures inside the fuse body during arcing. Fortunately the materials which can be used, have sufficient mechanical strength and elasticity to withstand the high pressures. In fact, they perform better in this respect than glass or ceramic, the materials used in common practice.

The fact that polymeric materials can be moulded, makes it easy to design the bodies in such a way that fastening the caps to the body can be done in an easy way; glueing and/ or soldering is not necessary anymore.

Fig. 1 shows a possible design of a miniature fuse using an ablative material. The caps are crimped on, attaching these firmly to the body in a way which is better able to withstand pressures than caps attaching by glueing or otherwise.

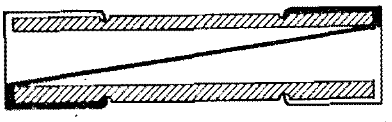

Fig. 1 Design of a miniature fuse using a plastic body and no sand filler.

Another advantage to choose for polymeric materials instead of glass or ceramic is the fact that fuse bodies of different manufacturing batches have less deviation in their dimensions. This reduces manufacturing problems. Plastic materials also weigh less than glass or ceramic; this reduces transportation costs for bulk packages. As a remark, a European patent has been filed for HBC miniature fuses without sand filler, using ablative materials [3].

## 4. RESULTS OF BREAKING CAPACITY TESTS

In reference [4] a computer simulation is described of the current interruption in a miniature fuse with an ablative inner wall. It is found that in case of short-circuit the current is reduced to a small value very rapidly. This conforms with experimental results of short-circuit tests which were carried out at Eindhoven University of Technology.

Some breaking capacity tests were done in a circuit for high breaking capacity tests according to IEC publication 127. Fig. 2 shows an oscillogram of a fuse with a rated current of 1A and a body made of an ablative material. The fuse had no sand filler. The voltage across and current through the fuse were measured with a digital recording system. (CAMAC, LeCroy) From the measured voltage and current traces, the arc power and arc energy as a function of time could be calculated.

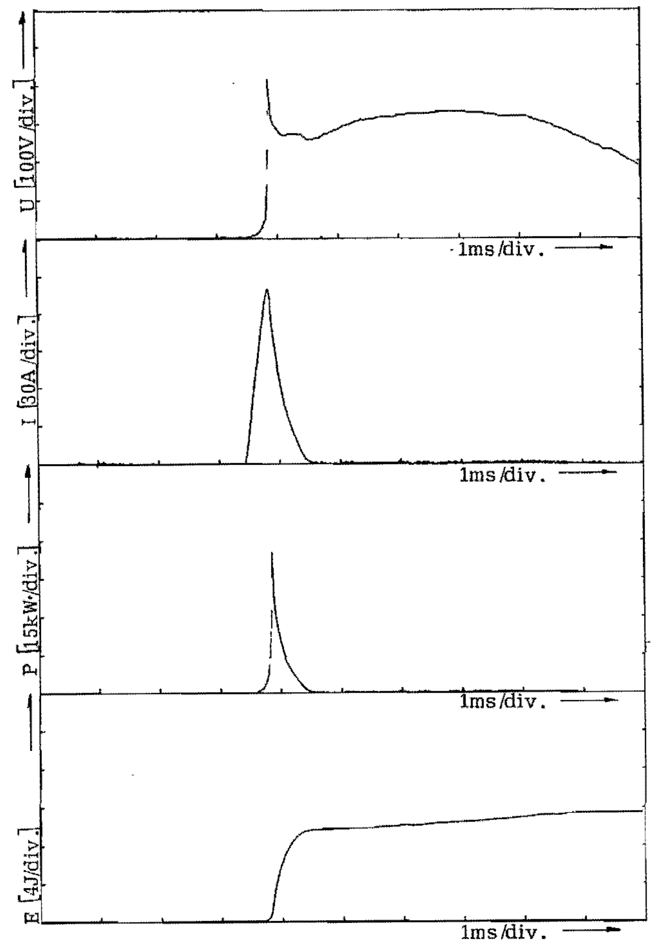


Fig. 2

Breaking capacity test on a miniature fuse (rated current of 1A) with ablative body.

U : voltage across the fuse.

I : current through the fuse.

P : arc power.

E : arc energy.

## 5. TESTING OF ABLATIVE FUSES

On miniature fuses with dimensions 5 x 20mm and 6.3 x 32mm IEC publication 127 is applicable. So it is obvious that a fuse with a body made of an ablative material must fulfil all the requirements mentioned in this IEC publication. For the new ablative fuses most attention should be paid to the breaking capacity test and the endurance test. As for the breaking capacity test, the fuse body has enough mechanical strength to withstand the high pressures which occur during arcing. Most attention has to be paid to the caps and their fastening to the body.

The problems which might arise during the endurance test are not the diffusion of tin out of the solder into the wire, because the wire is not soldered to the caps. In our case the endurance test is a test of the material which is used for the fuse body. When an inferior plastic is used, the wire will cut into the body due to the cyclical heating up and cooling down of the wire during the endurance test. This will lead to at least a bad electrical contact between wire and cap; it might even result in a premature interruption (no contact at all between wire and cap) of the fuse before the test is done.

As stated before, the fuse has to fulfil all the requirements mentioned in IEC publication 127. The use of polymeric materials for miniature fuses, however, makes additional tests necessary. Especially in the overcurrent range of a certain fuse, the body has to withstand relatively high temperatures; temperatures at which most common polymeric materials will melt or deform. So it is obvious that some sort of "high temperature test" has to be done. A possibility is to apply the so-called "step-test" or "current-test" which is mentioned in the proposed ISO standard for blade type electric fuse links [5] and the draft specification DIN 72581, part 3 [6]. These standards aim at car fuses for which the use of polymeric materials is already common practice. We think however that the "current-test" is also applicable to miniature fuses using ablative material. From experience with testing blade fuses for automotive applications it is well known that, based on such a "current-step-test", a rather quick and reliable judgement can be made regarding the quality of the fuse body. The test is described as follows :

"A current equivalent in value to the rating of the fuse link on test shall first be applied for a duration of 5 minutes. The current value shall then be increased in steps of 2.5% of the fuse link rating each 5 minutes until the element melts and the current flow is interrupted."

As miniature fuses have a higher fusing factor (1.5 - 1.7) than the blade fuse to which the above mentioned ISO standard is applicable (1.1 - 1.2), we suggest to start the "current-test" or "step-test" at a higher current value. Our experience is that a value of 1.4 times the rated current is a good starting point. (see fig. 3)

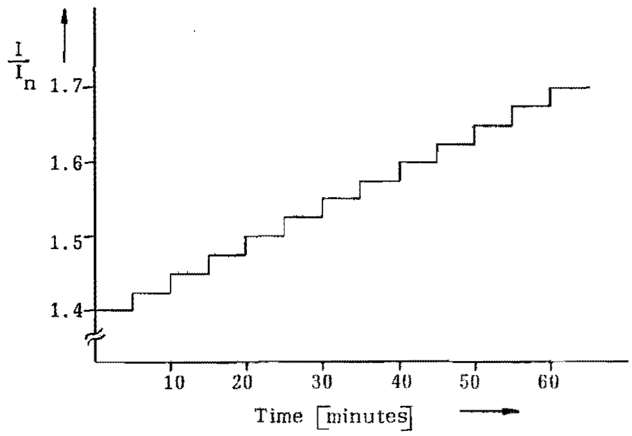


Fig. 3 : "step-test" or "current-test" $I_n$ is rated current.

During this test the highest temperature which might occur, is reached. A fuse may pass this test when it can be easily withdrawn from the test holder and no serious deformation or holes in the fuse body do occur. (deformation can be checked by carrying out the alignment test mentioned in IEC publication 127)

Another test wich should be done, is some sort of environmental test. It is a well-known fact that some polymeric materials are sensitive to fluctuations in ambient temperature and humidity. A test which might be of use is also described in the above mentioned proposed ISO standard. According to this standard the fuses are put into a climate chamber in which the relative humidity and temperature are varied between the boundaries as indicated by the shaded areas in fig. 4. The complete environmental test lasts for 10 cycles. (10 days)

A fuse may pass this test when the voltage drop measured at rated current did not increase by more than 10% of the value measured before the test.

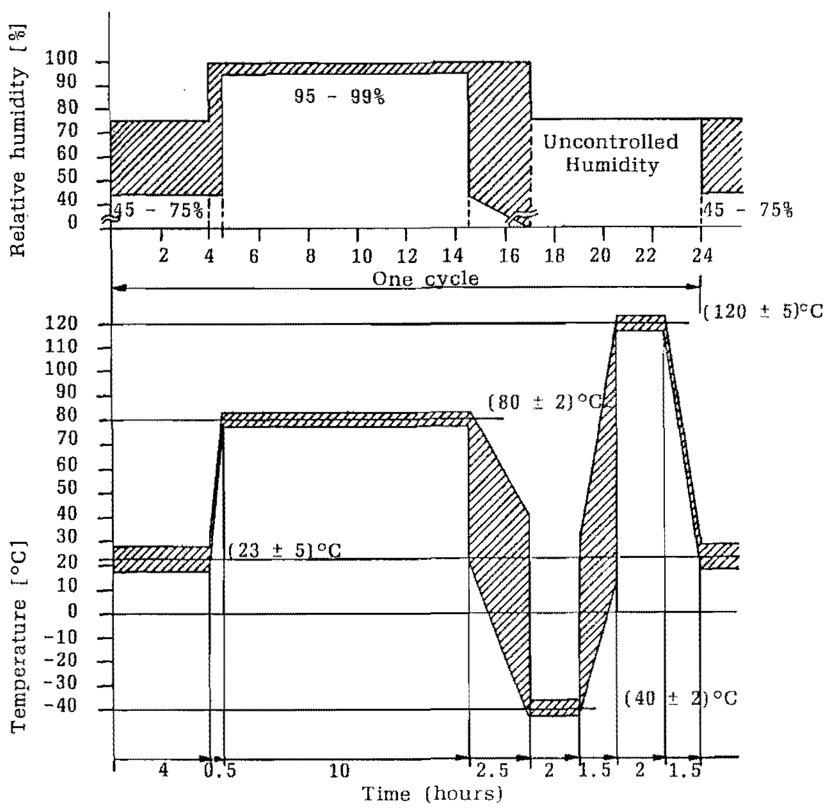


Fig. 4 : temperature and humidity cycle test. The test continues for 10 cycles.

## 6. CONCLUSIONS AND SUGGESTIONS

Our experimental results show that the use of ablative material is a possibility in miniature fuse technology. However, the materials used have to come up to meet special requirements. Especially high temperature behaviour is an important matter. This high temperature behaviour can be checked by two tests; the so-called "step-test" and a temperature cycle test. The temperature cycle test seems to be a (too) severe test; an ambient temperature of 120°C is probably never reached in common practice. However, this test is meant as an accelerated ageing test.

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Januar 1986

# Session VII

# MINIATURE FUSES 2

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