THE ROLE OF THE SEMI-ENCLOSED FUSE IN CIRCUIT PROTECTION

P. Morrell

'Additional security is obtained by Mr. Edison by inserting in every branch wire a 'Safety catch,' which is a short piece of lead wire that instantly melts if the strength of the current exceeds a certain value.'

(Comment on the Rules of the U.S. Board of Fire Underwriters, 1881).

This, the first fuse, invented by Thomas A. Edison in 1880, consisted of a 'weak spot' within the circuit intended to prevent overheating and destruction of conductors by excessive currents.

The device consisted of a piece of lead wire inserted in the circuit which was designed to melt when the current reached a pre-determined value. Its purpose was to protect the generator from damage due to excessive current and prevent damage to the building if short circuiting occurred between imperfectly insulated conductors.

Much time was devoted by engineers to the determining of wire diameters in order to prevent damage to lamps from over-voltage which frequently occurred with the early generators.

It was considered necessary to use lead wires for fuses as its low melting point resulted in a very small amount of damage to the surroundings when the fuse operated.

Circuit loadings increased rapidly with the years and the related higher current ratings required the use of copper for the fuse wire for currents in excess of approximately 5 amperes.

The operation of the copper wire fuse produced globules of molten copper and there was the fear that this would ignite the wood bases and cases then in use. This resulted in development aimed at containing the molten copper and one of the first improved types enclosed the copper wire element in a porcelain tube. The first British Patent which specifically referred to a fuse of high melting point wire, either silver or copper, in a porcelain tube was taken out by Laurence, Paris & Scott in 1889 (No. 6332). A later important development by the GEC, in the name of Hugo Hirst, is contained in British Patent No. 2249 of 1896. This covered the use of asbestos-covered fuse wire to minimise the effects of 'blow.'

Many stages followed in the development of fuses, they are generally well known to those involved in the fuse industry, and it is not the intention of this paper to cover them further.

Mr. Morrell is with M.E.M. Co. Limited.

Circuit protection devices developed along three main lines (1) Semi-enclosed fuses (2) HRC Cartridge fuses and (3) Circuit breakers. The use of semi-enclosed fuses continued in the U.K. and Commonwealth countries, but gradually in other parts of the world the emphasis moved from semi-enclosed fuses towards miniature circuit breakers whilst the development and use of the HRC cartridge fuse became universal.

The definition of a 'semi-enclosed fuse' taken from British Standard 3036: 1958 is, 'A fuse in which the fuse element is neither in free air (other than the air in any external containing case not forming part of the fuse) nor totally enclosed.' Normally a semi-enclosed fuse is of the rewireable type using an element of tinned copper wire and it has become standard practice to refer to a semi-enclosed fuse as 'a rewireable fuse.'

In the U.K. the use of semi-enclosed fuses for domestic circuit protection is widespread and figures supplied by manufacturers of both semi-enclosed and HRC cartridge type fuse units suggest that up to 90% of the market is for semi-enclosed fuses whilst the remaining 10% is probably divided equally between HRC cartridge pattern and miniature circuit breakers.

A somewhat different pattern of use appears for industrial pattern semi-enclosed fuses and the figures supplied by manufacturers of both semi-enclosed and HRC cartridge patterns show that the degree of usage varies with the rated current of the unit.

The smallest size of industrial fuse has a normal current rating of 20 amps and this size together with the next larger size i.e. the 30 amp rating use approximately 70% semi-enclosed fuses compared with 30% HRC cartridge type.

The proportion of semi-enclosed fuses in use decreases with increased current rating being about 60% for the 60 amps rating and about 50% for the 100 amp rating. At a current rating of 200 amps, all fuses are of the HRC cartridge pattern, manufacturers having discontinued production of this rating in semi-enclosed pattern some years ago.

The performance of the semi-enclosed fuse is often queried and some engineers appear to be prejudiced against their continued use.

Semi-enclosed fuses commercially available have somewhat reduced breaking capacity ratings compared with HRC cartridge fuses, but the absence of any significant problems associated with these reduced breaking capacity ratings amply demonstrates that they are perfectly satisfactory for all normal applications. Their breaking capacity ratings are very similar to those applying to many miniature circuit breakers where the breaking capacity rating is seldom criticised.

Domestic pattern semi-enclosed fuses normally have a rated breaking capacity of between 1000 amperes and 2000 amperes depending on current rating and individual manufacturer.

This breaking capacity applies to all current ratings and as the physical dimensions of all current ratings are often identical the breaking capacity is not related to the size of element wire fitted and is achieved over a wide range of element sizes.

Industrial pattern semi-enclosed fuses differ from the domestic pattern in several ways, not least of which is physical size. The need for a longer wire element due to the higher voltage and current ratings dictates a larger unit which automatically allows for higher breaking capacity values.

Typical values are as follows:-

20 amp rating	-	2000 amperes
30 amp rating	-	2000 amperes
60 amp rating	-	2000 amperes to 4000 amperes
100 amp rating	-	4000 amperes to 6000 amperes

Economically the semi-enclosed fuse cannot be equalled and in these days when economy is of paramount importance it would be imprudent to dismiss this important factor without giving due consideration to the level of circuit protection necessary for any particular installation.

They have a further advantage which is not always appreciated - that of being less often maltreated. The dangerous expedients adopted by ignorant users to 'repair' blown cartridge fuses, such as wrapping them in silver paper, or soldering wire between the outside of the cartridge end caps, has proved, in practice, to cause more trouble than the risk of them overwiring semi-enclosed fuses.

One of the principal reasons for the abuse of cartridge fuse is that a replacement is not always readily available whereas a short length of copper wire as used for the repair of a blown semi-enclosed fuse is usually easy to obtain. It is quite true also that most users are ignorant of the consequences of such abuse to cartridge fuses.

Manufacturers of various types of protection equipment have all seen classical examples of the maltreatment of blown cartridge fuses and the damage caused to the equipment when another fault condition occurs, but cases where damage has been caused by mistreatment of semi-enclosed fuses are unknown. Most manufacturers of semi-enclosed fuses will endorse the view that evidence of problems due to their inherent lower breaking capacity is practically nil, we believe this to be due to the fact that cognisance has always been taken of the overall limitations of the fuse and they are therefore installed in situations where a device with a higher breaking capacity is not necessary.

In the majority of domestic situations quite low prospective short circuit currents are realised due to the resistance of the distribution cables, it is also a fact that most fault conditions occur in equipment at the end of the circuit cable and not at the distribution board. There are some special situations such as high rise blocks of flats where prospective currents can be much higher and in these situations the use of the semi-enclosed fuse is restricted.

Semi-enclosed fuses have a maximum fusing factor value of 2.0 when fitted with the size of element wire specified by the manufacturer. This requirement originates from the IEE Regulations for the Electrical Equipment of Buildings (8th Edition), 1924 which specified that with 100% over-current a fuse should blow within one minute with a fuse-wire of tinned copper, or within two minutes with a fuse-wire of lead/tin alloy.

A test to check the blowing current of a fuse was incorporated in British Standard 88 dated 1931, this specification being the one covering 'fuse cut-outs for ordinary duty.'

Following the issue of this British Standard work was carried out by the Electrical Research Association to investigate the possibility of using one size of wire for all semi-enclosed fuses of a given current rating. Although there was some divergence from a mean size among fuses of different makes due to design expediency, the variation was not usually more than one standard wire gauge. The result of this work was a list of mean sizes for various current ratings and this formed the basis of a table of recommended wire sizes incorporated in the 10th (1934) edition of the IEE Regulations for the Electrical Equipment of Buildings.

This table still appears in modified form in the latest (14th) edition of those regulations, the wire sizes now being expressed in metric values and sizes of lead/tin alloy elements having been deleted.

In 1958 British Standard 3036 was issued, this being devoted entirely to semi-enclosed fuses, and this specification is still current at the present date. Work is in hand to amend the specification in line with present day practice and also to introduce metric values where necessary. BS 3036 contains a great deal of useful information to the electrical engineer and its appendices which comprise a large part of the standard give expert guidance on the use of semi-enclosed fuses.

Standards for semi-enclosed fuses have been issued by certain Commonwealth countries as follows:-

Australia - SAA AS 3135 - 1973. This specification, in metric units, covers semi-enclosed fuses for A.C. circuit with a maximum current rating of 100 amperes and a maximum rated breaking capacity of 4000 amperes.

India - IS 2086 - 1963. This specification covers semi-enclosed fuses with a maximum current rating of 100 amperes and a maximum rated breaking capacity of 4000 amperes.

South Africa - SABS 174 - 1955. This specification covers 'rewirable' type fuses in current ratings up to 100 amperes maximum for both A.C. and D.C. circuits. The maximum breaking capacity rating is 4000 amperes.

New Zealand - NZS 1951. This is British Standard BS 3036: 1958 endorsed for use as a New Zealand Standard.

In conclusion it appears that semi-enclosed fuses will be used in large quantities for many years to come and this fact should be recognised by everyone associated with the electrical industry. That they will eventually be superseded by other protective devices whether it be circuit breakers or HRC cartridge fuses, seems, on balance,to be likely but the change over could take many years to accomplish. It has been suggested in some quarters that the change over should be effected by legislation, but with a device which performs its function with so few problems, we feel that any change should be allowed to come about as dictated by the combination and interaction of many technical and economic considerations as they emerge, rather than be forced by mandatory measures however well intentioned.