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Comparison of Tin and Silver Fuse Links

One of the most controversial subjects regarding fuse links concerns the relative merits of tin versus silver fusible sections. Cooper Power Systems has made both types for a number of years. However, the silver links were made primarily for competitive purposes. In our opinion, operating experience and many years of engineering research show a superiority of tin over silver for overall maximum performance. To bear out this claim, let us compare tin and silver links point by point. The major factors to be considered are:

1. Heating due to continuous current;
2. Effect of ambient temperatures; and
3. Short-time ratings.

Heating Due to Continuous Current

Two major considerations must be taken into account in determining the proper fuse link that should be applied at any given point:

1. The amount of continuous current that the link will be required to carry; and
2. The link properly coordinates with adjacent links in the system or with reclosers, as the case may be.

The continuous current carrying ability of the link depends upon the heating of the link. Cutouts using silver links generally run about 5°C hotter at the contacts than a comparably rated tin fuse link at the rated current of the link. This was predominately true with the old "N" rated tin fuse link. However, with the new EEI-NEMA fuse link, the tin link will run cooler at its rated current than a comparable silver link. This is true because the melting current of the EEI-NEMA tin links is approximately 220% of the link rating, whereas the melting current of the "N" rated links was about 150% of the link rating. This means that the EEI-NEMA tin links can carry about 150% of their rating without overheating. Silver links, on the other hand, have a melting current approximately 200% to 220% of the link rating because it is not possible to operate the silver links any closer to their melting current without overheating the cutouts.

The melting temperature of silver is 960°C, whereas the melting temperature of tin is only 231°C. This means that the corresponding operating temperatures will be some percentage of the actual melting temperatures.

The comparative heating effects of tin and silver fusible sections can be seen in Figure 1.

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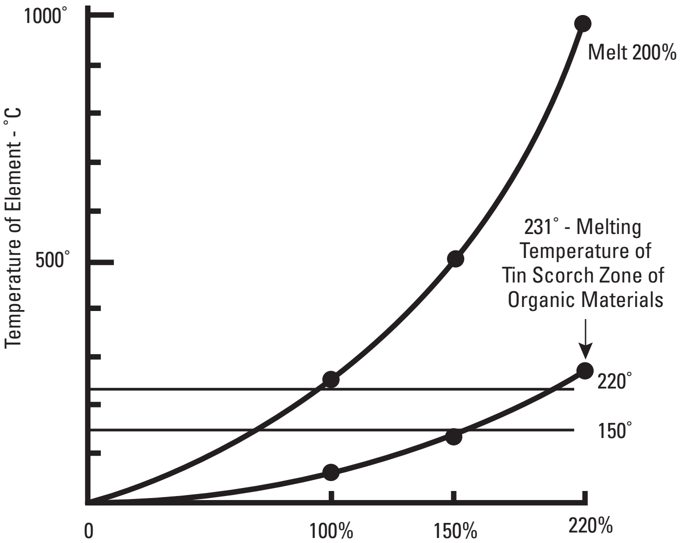

Figure 1. Comparative heating of tin and silver EEI-NEMA links

The temperature zone in which fibre and bakelite start to scorch is between 150° and 220°C. Silver links have a tendency to damage paper or fibre fuse link auxiliary tubes, especially if they happen to be operating over their rated current. Tin links, on the other hand, prevent unnecessary outages from cutout failures due to overheating because of their much cooler operating temperature.

Since no actual test data was available on operating temperatures, a series of tests were performed to obtain this information.

The tests were performed on three PVD-56, 50 ampere, 5kV cutouts. One was fused with a Cooper Power Systems type K, 50 ampere tin link, catalog number FL3K50; another with a Cooper Power Systems type K, 50 ampere silver link, catalog number FL6K50; and the third with a S & C 50 ampere, type K silver link, catalog number 2650050. Temperatures were obtained by means of thermocouples placed on the fusible elements and on the fibre liner of the cutout tube. The latter thermocouples were positioned axially in the tube so as to be adjacent to the fusible section.

The temperatures were obtained after stable conditions were reached, and are shown in the following table:

Amps Thru Link	Total Temperature - ºC at 25ºC Ambient					
	Cooper Power Systems Tin Link		Cooper Power Systems Silver Link		S & C Silver Link	
	Element Wire	Fibre Liner	Element Wire	Fibre Liner	Element Wire	Fibre Liner
50	62	44	213	48	—	50
75	105	72	460	90	—	110

The 50 ampere test was for a duration of 133 hours. At the end of this time, the links and cartridges were carefully examined. There was no evidence of scorching on either the fuse link tubes or the liners of the fuse cartridges.

The 75 ampere test was run for 21 hours, at which time scorching was observed on the silver fuse link tubes. None of the fibre liners in the cutout cartridges or the tube on the tin link were damaged. On the S & C link, a small hole was burned in the tube, and it was so brittle that the tube broke when the link was removed from the cartridge. On the Cooper Power Systems silver link, the tube was still intact, but was scorched and brittle in a region just below the fusible section.

It will be noted that the S & C links produced higher cartridge temperatures than the Cooper Power Systems silver links. This Is due to the difference in construction of the fusible elements of the links. On the S & C link, the long element is spirally coiled, in effect, forming a heater coil and concentrating the heat within an axial distance of 3/4 of an inch. On the Cooper Power Systems silver link, the element is straight and the heat developed is spread out over an axial distance of 1-3/4 inches. It is interesting to note that the scorching on the Cooper Power Systems link tube did not occur in the section surrounding the crimp sleeve that joins the leader to the ferrule section. This is probably because the sleeve is large in diameter, and in closer proximity to the tube.

It appears that under normal operating conditions, there is not much danger of scorching fuse cutout cartridges when silver links are used, as the tube on the fuse link acts as an insulating barrier keeping the intense heat of the fusible element from reaching the cartridge walls. The fuse link tube on a silver link may be damaged when the link is required to carry loads greater than its rating. This may impair low current clearing ability.

With tin links, temperatures under all conditions are well below the scorching range of the tubes, and no damage is possible.

Another factor which enters into the overheating of cutouts with silver links is the construction used in the manufacture of most silver links. In this type of construction, the silver element is fastened at both ends by a mechanical crimp joint. A mechanical joint permits oxidation to develop between the parts, increasing heating to the point where time-current characteristics may become unreliable.

Figure 2 shows the comparative heating between a tin link with a soldered fusible section, and a silver link with a mechanically crimped fusible section.

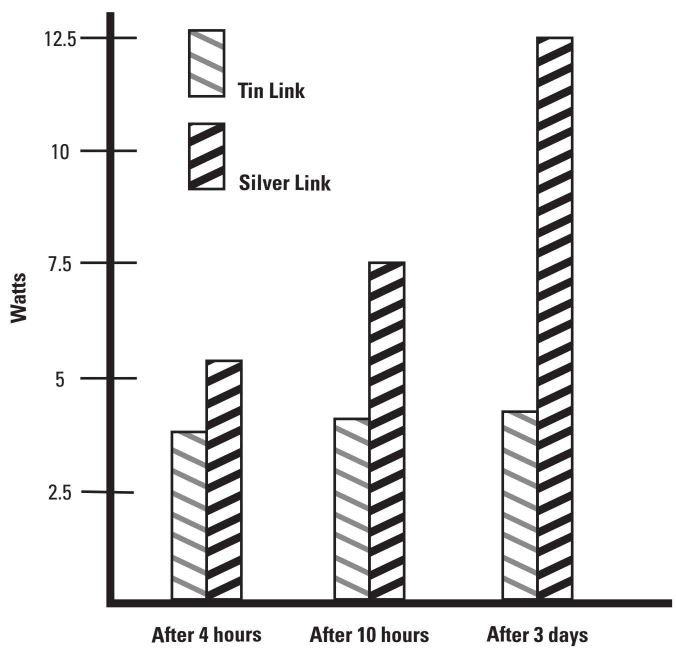

Figure 2. Comparative heating

Actually, on Cooper Power Systems links, 25 through 100 amperes, the element is die cast right onto the shank and leader of the link. This ensures accuracy, as well as an excellent joint. On links below 25 amperes, the wire fusible element is soldered to the shank and leader, and it has been the contention by silver link advocates that this soldered joint leads to the unreliability of links. This is not true. The time-current characteristics of fuse links are in no way affected by the amount of solder used to fasten the element to the shank or leader.

Effect of Ambient Temperature

According to NEMA standards, time-current curves of fuse links are obtained at an ambient temperature between 20ºC and 30ºC, with no initial load or current passing through the fuse link. This means that before the link is blown to determine its melting time, the current responsive element is at an average temperature of 25ºC.

If the current responsive element is at any temperature other than 25ºC, the melting time is different than what is shown on the published curves. Temperatures above 25°C, which would occur when links are used at higher ambient temperatures or when they are carrying loads just prior to melting, will cause the links to blow sooner than shown on the time-current curves. Conversely, links carrying no load and operating at a very cold temperature will take longer to blow than what time current curves show.

Since the melting points of tin and silver are so different, the preload and ambient temperature will affect the melting characteristics of tin and silver links to a different degree. In general, ambient temperature will have less of an effect on silver links than tin because of the higher melting temperature of silver, but a given percent of preload will have more of an effect on the characteristics of silver than tin.

When individual links are considered, the smaller change in characteristic due to ambient temperature for silver links appears to be an advantage of silver links over tin links. In a coordinated system, however, all fuse links operate at approximately the same ambient temperature, so if all silver links or all tin links are used on a system, the time-current characteristic curves will shift equally, and changes in ambient temperature will be of no consequence.

Actually, the larger percentage of shift of the tin links is more advantageous when coordinating with reclosers because it more nearly approaches the shift of the recloser curves.

Short Time Ratings

The minimum melting time-current curves for fuse links are based on tests where a number of fuse links are blown at various currents and a curve is plotted through the average of these points. This is the average melting curve. Manufacturing tolerances are added to obtain the minimum melting curve.

When one device protects another device on a coordinated system, the protected device is going to be subjected to the short-time fault which caused the protecting device to operate. Just how close this short time fault can approach the minimum melting curve of a fuse link when used as the protected device and still allow the link to retain its characteristics depends on several factors. The major factors are the metal used and the preloading of the link.

A certain amount of time is required for a fuse link to reach its melting temperature. This time varies with the type of metal used for the fuse element. Additional time is also required for the heat of fusion to be added before the link becomes completely liquid. Although experience has shown that a certain amount of heat of fusion can be added before a fuse link is damaged, if too much heat of fusion is added, the molten metal will change physical dimensions so that when the fuse link cools down again it will not have the same characteristics. The fuse link is then considered damaged because it no longer conforms with its time-current characteristic curve.

To see the relationship of the time rate of heating between silver and tin links of equal characteristics, refer to Figure 3.

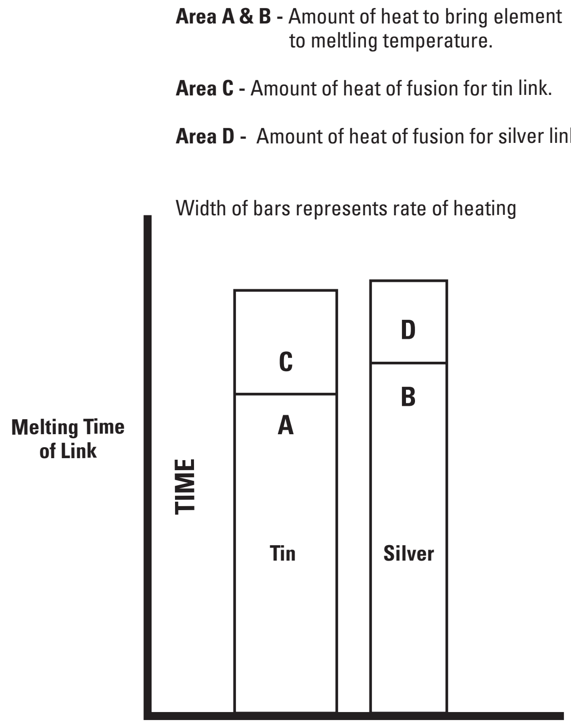

Figure 3. Relative heating time of tin and silver links with equal time-current characteristics

As seen from Figure 3, the time required to reach the melting temperature of the silver link is greater of than the time required to reach the melting temperature of the tin link. The time required for the addition of the heat of fusion of the silver link is, therefore, less than the time required for the addition of the heat of fusion for the tin link. Theoretically, therefore, it can be seen that the sliver link can be operated closer to it's minimum melting time before damage occurs, if the link has not been preloaded.

Time-current characteristic curves are plotted by using cold links. In actual operation, however, the links are at a continuous current of some value at the time a fault might occur. This preloading has raised the temperature of the link so that it will not require as long to melt as it would if there was no preloading. Because of the higher melting temperatures of silver links, preloading has a much more pronounced effect on silver links than on tin links. Again, if we theoretically consider preloading only, the tin link can be used much closer to its minimum melting curve before damage occurs.

The following calculations for both tin and silver links were made to clarify these effects.

When the fuse links are carrying their rated current, or 100% preload prior to melting, the tin link will melt at 89% of its published time; whereas, the silver will melt at 84% of its published melting time.

As preload on a tin link and a silver link increases, the difference between the temperatures of the fusible elements increases very rapidly. For EEI-NEMA type K fuse links, at a 25% preload, temperature rise of the element of a tin link is only 4-1/2ºC, while that of a silver link is only 15ºC. This makes the silver element only 11ºC hotter. At 50% preload, a tin element runs 9ºC rise, a silver 42ºC, or the difference is 33ºC. At 100% preloads, tin runs 36ºC rise, a silver 188ºC, or the difference being 152ºC. At the high preloads, temperature difference is great enough to have a pronounced effect on the melting characteristics of silver links as well as on the higher heating of the cutout contacts in which the link is mounted. At the lower preloads, however, the difference is small enough to be just about negligible

The amount of current in percent of the minimum melting time which a link can take without being damaged is difficult to determine accurately. S & C claims that their silver links are not damageable. We don't believe this is true, as we have been able to damage silver links. It is probably that silver links are less damageable than tin. We estimate that the factor for silver links is about 5% and for tin links about 10%. A tin link without any preload and at 25ºC starting temperature can be subjected to a current to within 90% of its melting time without being damaged, and a silver link to within 95% of its melting time without being damaged.

Since time-current curves are obtained on the basis of a certain ambient temperature and no preload, you can readily understand that some factor must be applied when links are actually used in the field where they may be subjected to high ambient temperatures and preload conditions. That is the basis for the 75% factor that we recommend in coordinating links. Roughly, this 75% is made up of about 10% for damage, 9%for preload, and 5% for extraordinary ambient temperatures. These add up to 24% which, when subtracted from 100%, gives a factor of 76% which we round off to 75%.

Since the same is true for silver links, we do not agree with S & C's statement that no factor is required for this type of link. We believe their factory should also be close to 75%—5% for damage, 17% for preload, and 2% for ambient. Here again, this adds up to 24%, giving a factor of 76%, or exactly the same as for tin links.

We have been using this 75% factor for many years, and quite a few other manufacturers use this same factor. It apparently has given good results, as we have never had any complaints that our coordination table, which based on this factor, did not work out satisfactorily. We believe this factor is rather conservative, and that in cases of close coordination, a larger figure may be used. Thus, if a customer applies links so that the preloading is considerably less than 100% and the ambient temperatures are rather low, a factor of 85% or 90% may be justified.

Tin does have the characteristic in that it produces a slower link. This is shown by the fact that silver cannot be used for T type links, but only for the fast K type, whereas, tin can be used for either type. If one standardizes on this type, one will have to use tin links, as no silver links are available.

Conclusions

Strictly from a coordination standpoint , silver links could possibly be coordinated to slightly higher values of current. However, this additional value would be very small considering equal preloading of the links.

Tin links will more accurately coordinate with reclosers because the shift in the time-current characteristic curves for the tin links more nearly approaches that of a recloser due to ambient temperature changes.

Because of their high operating temperatures, silver links are very prone to overheat and burn cutouts. They cannot be operated above their rating. EEI-NEMA tin links, with the same time-current characteristics, on the other hand, actually can be operated continuously at about 150% of their rating, provided this current does not exceed the rating of the cutout in which the link is used.

The change in time-current characteristics due to ambient temperature Is a small consideration in the application of fuse links because the ambient temperature Is going to be about the same for all the links on the system.

From the above analysis, it can be concluded that tin links will give maximum performance and protection regardless of whether they are used for overload protection or coordination purposes, even if the links are overloaded.

The silver link will give good performance when used for coordination purposes, if load-carrying ability Is of no consequence, and the links can operate below their capacity.

It is for these reasons we feel that tin fuse links give the best all-around performance.

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