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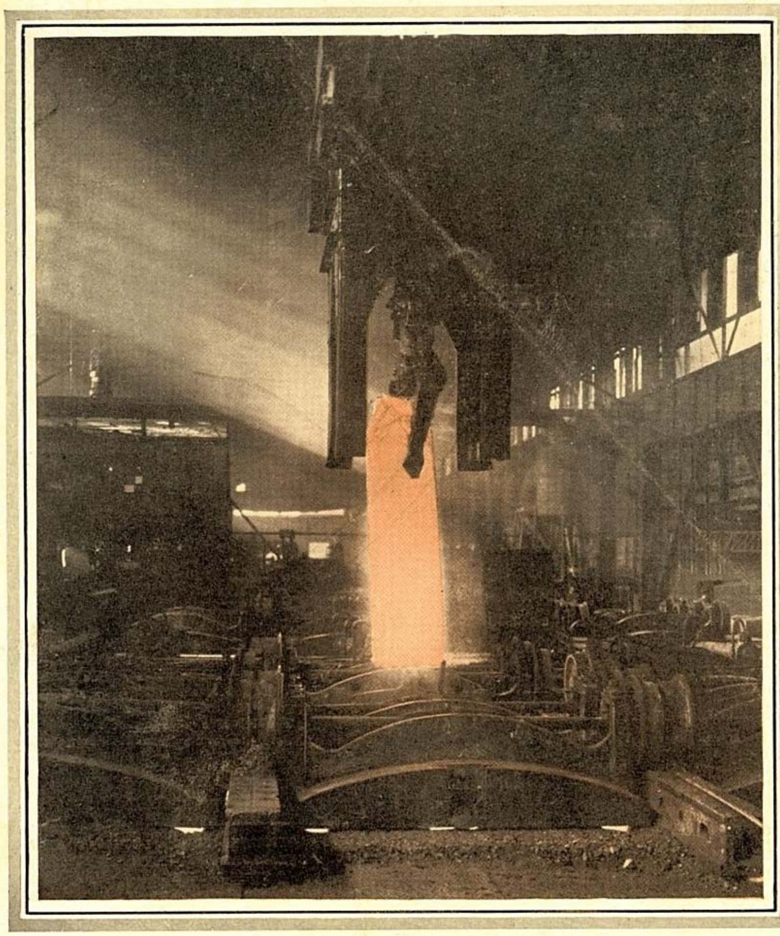

HEAT AND ELECTRICITY COMBINE
TO PREPARE STEEL FOR ITS WORLD'S WORK

Short-time Current Carrying Capacity of Copper Wire

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As POWER systems grow in size the possible concentration of energy at some point where a short-circuit or flashover to ground occurs becomes correspondingly greater; and one of the predominating present-day requirements of electrical apparatus is its ability to withstand short-circuits. This applies also to the manner in which the equipment is installed and utilized, in other words, to the design of the power house, substation, transmission or distribution line. The utilization of copper wire in apparatus or as some connecting link in the scheme for controlling short-circuit currents should therefore be considered not only from the standpoint of continuous carrying capacity but also from the standpoint of its short-time current carrying capacity.

The ability of copper wire to withstand heavy currents for short periods of time, varying in length from a fraction of a second to a few seconds, has been studied; and the results are given in this article. One of the applications where a knowledge of the short-time current carrying capacity of copper wire is of value is where copper wire is used for bonding and grounding the insulator pins of wooden pole transmission lines or distribution lines operating at 10 kv. or above. This bonding is occasionally employed for the purpose of preventing pole-top fires which might occur during a fog or rain as a result of minute current leakage over the insulators, across the crossarms, and down the pole.

In case of a flashover of an insulator to ground, or the simultaneous flashover of two insulators, it will be necessary to have the copper wire used for bonding of such size that it will not be melted by the short-circuit current within the time required to clear the faulty line from the system. This time depends upon the protective relay settings and the speed of operation of the oil circuit breakers connected to the terminals of the line in trouble.

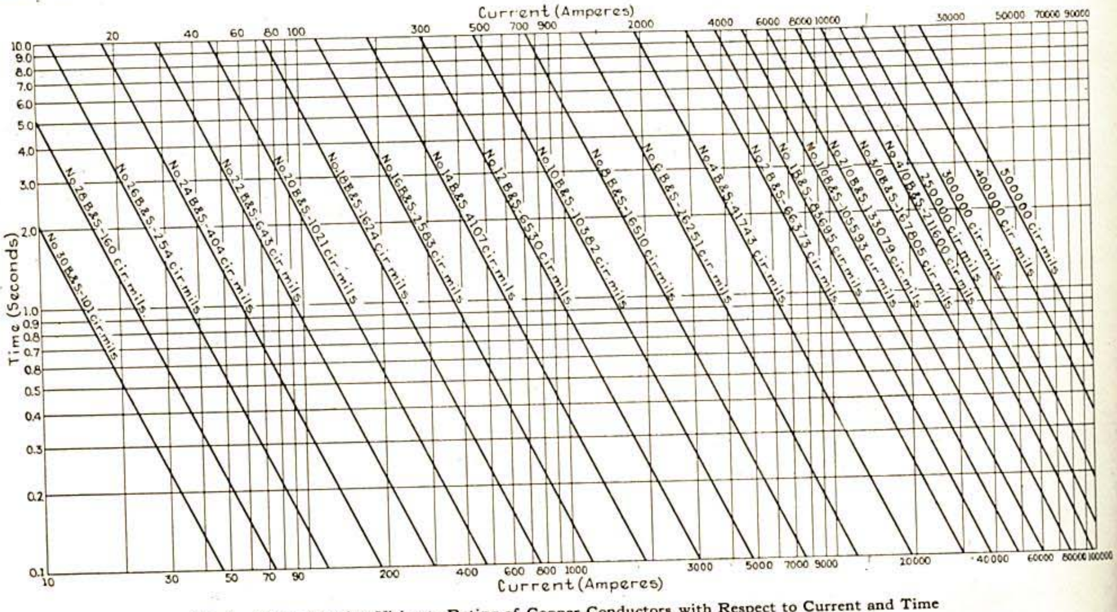

Fig. 1. Chart Showing Ultimate Rating of Copper Conductors with Respect to Current and Time

The consideration of short-time current carrying capacity of a copper conductor is also desirable when laying out the ground busses in generating plants and substations. However, the carrying capacity of the joints, a function of the temperature at which the soldering or brazing will melt, is more of a determining factor in station design than in the bonding of wooden pole transmission line insulator pins.

The values of short-time current required to melt copper conductors, as given by the chart shown in Fig. 1, were calculated by the formula:[1]

$$33\left(\frac{I}{A}\right)^2 S=\log_{10}\left(\frac{t}{274}+1\right)$$

(1) This formula was developed by I. M. Onderdonk.

where

I = the current in amperes

A = the cross-sectional area of the conductor in circular mils

S = the time in seconds that the current I is applied

t = the difference in temperature or the temperature rise of the copper.

The calculations are based on a value of 1083 deg. C. for the melting point of copper and on the following assumptions:

(*1*) Ambient temperature of 40 deg. C.

(*2*) Radiation neglected due to short time.

(*3*) Resistance of one cm.^{3} of Cu at 0 deg. C. taken as 1.589 microhms.

(*4*) Temperature coefficient of Cu at 0 deg. C. taken as 1.234.

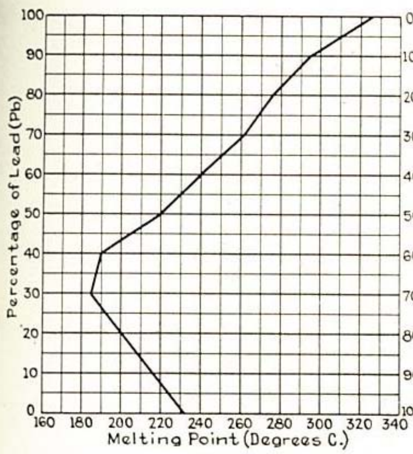

Fig. 2. Melting Points of Tin and Lead Alloyed in Various Proportions

It must be understood that the application of the foregoing formula is limited in that it applies only to short periods of time and that heat storage only in the copper itself is considered. When a long period of time is involved, *i.e.*, in the order of several minutes, radiation becomes a factor and the copper wire would require a longer time to reach melting temperature than indicated by the formula.

The values for the charts were calculated by solving for I as follows:

$$33\left(\frac{I}{A}\right)^2 S = \log_{10}\left(\frac{t}{274}+1\right)$$

$$\left(\frac{I}{A}\right)^2 = \frac{\log_{10}\left(\frac{t}{274}+1\right)}{33\,S}$$

$$\frac{I}{A} = \sqrt{\frac{\log_{10}\left(\frac{t}{274}+1\right)}{33\,S}}$$

$$I = A\sqrt{\frac{\log_{10}\left(\frac{t}{274}+1\right)}{33\,S}}$$

The temperature of the melting point of copper is taken at 1083 deg. C. and the temperature of the air at 40 deg. C.

The temperature difference is then 1083 deg. $-$ 40 deg. = 1043 deg. C.

The time is first taken as 1 second

Then

$$I = A\sqrt{\frac{\log_{10}\left(\frac{1043}{274}+1\right)}{33\times 1}}$$

$$= A\sqrt{\frac{\log_{10} 4.807}{33}}$$

$$= A\sqrt{\frac{0.68187}{33}}$$

$$= A\sqrt{0.02066}$$

$$= A\times 0.14374 \qquad (S = 1 \text{ sec.})$$

In considering a longer time, 10 seconds is taken as the maximum.

Then

$$I = A\sqrt{\frac{0.68187}{33\times 10}}$$

$$= A\sqrt{0.002066}$$

$$= A\times 0.04547 \qquad (S = 10 \text{ sec.})$$

The same formula can be applied where the melting temperature of the soldering materials used in making up the joints in the copper conductor is the determining factor. In the case of ordinary solder, the value of t would be about 183 deg. C. minus the temperature of the air. The curve in Fig. 2, taken from the Smithsonian Physical Tables, shows the melting points of an alloy of tin and lead in a full range of proportions. Where brazing is used, a reasonable value for t is 450 deg. C. minus the temperature of the air.

The author wishes to express his appreciation of the suggestions given by W. W. Lewis and J. E. Clem in making a study of this subject.