AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS.

TWELFTH GENERAL MEETING.

Niagara Falls, N. Y., June 25, 26, 27 and 28, 1895.

The opening session of the twelfth General Meeting of the INSTITUTE was called to order by the Secretary at the Cataract House, Niagara Falls, on Tuesday June 25th, at 10.15 A. M. Two hundred and five members and guests were in attendance.

The Secretary announced that it had been the intention of Past-President Houston to attend the meeting, but he had been unexpectedly detained.

He then introduced the President-elect, Dr. Louis Duncan, of Baltimore, who on taking the Chair was greeted with a hearty round of applause.

President Duncan then introduced Hon. O. W. Cutler, Mayor of Niagara Falls, who addressed the INSTITUTE as follows:

Mr. President and Gentlemen of the AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS:—In behalf of the City of Niagara Falls, I extend to you a hearty and cordial welcome within our gates at this time. We have anticipated your coming with a great deal of pleasure and interest, believing as we do that it is fraught with great benefits to our city. You are doubtless all aware of the progress that has been made in the development of our unrivalled power, and of the proposed transmission and application of it by means of electricity, for which we are so largely indebted to your profession. I venture to say that you will see much in the line of your vocation to interest you while here, in visiting and inspecting our various enterprises, which, as I have already intimated, are of deep interest to the world at large, as well as of great importance to the material interests of our own locality. I trust that your stay here will be as pleasant as it will be interesting.

Again I welcome you and take pleasure in extending to you the freedom of our famous and romantic city. (Applause.)

President Duncan then presented Mr. Walter E. Harrington, of Camden, N. J., who read the following paper:

PROPERTIES OF FUSE METALS WHEN SUBJECTED TO SHORT CIRCUITS.

BY WALTER E. HARRINGTON.

In the TRANSACTIONS of the INSTITUTE, May 1893, page 251 is a paper by Charles P. Matthews, "On the Behavior of Fuse Metals in Direct and Alternate Current Circuits." The paper deals quite exhaustively with the law established by Preece, Prof. Forbes and others, bearing on the relation existing between the diameter of fuse metals and the minimum currents required to fuse the metals, when sufficient time elapses for the fusion to occur.

The law as enunciated is $C = a d^{\frac{3}{2}}$ wherein

C = Current in amperes,

d = Diameter of wire in inches,

a = Constant depending on the metal.

The law is not rigorously true but can be depended upon very closely, particularly in the smaller diameters. In the larger diameters the law certainly does not hold true, as has been shown by different observers.

To be true and express the real relation, the constant a should be expressed as a function of d ; and as far as my observation has led me, I think a is a linear function of d . It is not the purpose of the writer to elaborate on the various factors entering into the causes underlying the variability of fuse metals. The ground has been pretty thoroughly covered.¹

1. "Safety fuses versus Magnetic Cut-outs," by W. E. Harrington, *Electrical World*, April 29th, 1893, vol. xxi, No. 17.

Paper read before American Street Railway Association, Milwaukee, October 1893. "Street Car Magnetic Cut-outs," by W. E. Harrington.

On page 261 of Mr. Matthews' paper it is briefly mentioned that fuse metals rarely fuse in practice, under the conditions that the law as obtained demand.

Mr. Preece on short-circuit tests made by him writes in a very vague manner covering the results as obtained.

In the course of his professional work the writer has frequently had occasion to desire to know what current would flow through fuse metals on 500-volt short-circuit work. There being absolutely no literature on the subject, and the data to be obtained only by experiment, led to the following series of tests :

The tests were conducted in the power station of the Camden Horse R. R. Co., Camden, N. J., during August, 1894.

The testing room was about 30 feet away from the 'bus bars of the main station switchboard. No. 2 B. and S. gauge copper wires led from the 'bus bars to the testing table. At the switchboard the two leads were connected, one to the ground 'bus bar direct, the other through a 100-ampere knife-blade switch to the trolley side of a Westinghouse magnetic circuit breaker, whose range of adjustment was from 250 amperes to 500 amperes in 50-ampere steps. In the testing room the wires were arranged diagrammatically, as shown in Fig. 1.

A, was a special fuse block whose terminals were protected by oil, leaving 3" of fuse in the atmosphere.

B, fuse metal whose fusing current on short-circuit was to be determined.

Paper read before the National Electric Light Association at its 17th Convention, Washington, D. C. Feb. 27, 1894. "Faults Incident to the Protection of Lighting and Power Circuits," by L. T. Stanley and W. E. Harrington.

Discussion of Mr. C. P. Matthews' paper "On the Behavior of Fuse Metals in Direct and Alternate Current Circuits." — TRANSACTIONS A. I. E. E., vol. x, page 266.

Catalogue of the Shawmut Fuse Wire Co., 161 High Street, Boston.

"Copper Fuses." Letter by B. S. Lanphear to the *Electrical World*, Jan. 19th, 1895, vol. xxv, No. 3.

Editorial Columns of the *Electrical Engineer*, Sept. 16, 1891, regarding the irreliability of fuses in alternating current work.

Proc. Roy. Soc. Dec. 22, 1887, Article on fusing currents and giving constants for different metals for Law $C = ad^{\frac{3}{2}}$ has the following values :—

Copper	$a = 10244$
Aluminium	$a = 7585$
Platinum	$a = 5172$
German Silver	$a = 5230$
Platinoid	$a = 4750$
Iron	$a = 3148$
Tin	$a = 1462$
Alloy (Tin 1, Lead 2)	$a = 1318$
Lead	$a = 1379$

"Fuse results were determined by using six-inch lengths of wire."

"On the Heating Effects of Electric Currents," by W. H. Preece, *Proc. Roy. Soc.* April 3rd, 1884.

Reports British Association, 1882. Paper by Prof. Forbes.

c, a c-s magnetic circuit breaker carefully calibrated throughout its range, not only for its adjustment, but also as well for 7, 14, 20, 30 and 40-turn coils. A Weston standardized ammeter was employed during calibration. Since the construction of the c-s magnetic circuit breaker is such that the adjustment depends only on weight and distance, the circuit breaker does not vary after use.

d, a 100-ampere knife-blade switch.

FIG. 1.

The fuse metals tested were placed in fuse block A and switch D thrown. This was repeated with the same size fuse metal a sufficient number of times to find the adjustment of the c s magnetic circuit breaker which the current flowing would not open, also the adjustment at which the current flowing would open. The current which actually flowed would be somewhere between the two indications as obtained. The accompanying tables give the mean of the two readings. The tests were made during the middle of the day when the loads were light on the power

station. A 200 k.w., G.E. 4-pole, and a 100 k.w.-Edison bipolar generator were running during the obtaining of the following data.

The sizes of fuse wires employed was such that the current flowing through them would not exceed 500 amperes, this being determined by the adjustment of the Westinghouse magnetic circuit breaker referred to before.

In the following tables the first column gives the size of wire in B. & S. gauge; the second column gives the circular mils.

The third column gives the mean of determinations as shown by the indications of the c-s magnetic circuit breaker.

The fourth column gives the constant B entering into the formula $C = B d^2$, where

C = current in amperes passing through the fuse metal on a short-circuit.

d = diameter of fuse metal in inches.

B = constant depending on metal and voltage of circuit short-circuit is made on.

The writer noticed that the values as obtained in the tests when compared with the circular mils of the wires tested showed a very close proportionality, showing that the fusing currents on short-circuits followed the law of the square times a constant.

TABLE I.

COPPER.

B. & S. Size Gauge.	d^2 C. M.	S. C. Amps.	B
30	100	37	380,000
29	126	44	350,000
28	159	62	390,000
27	201	80	398,000
26	254	116	456,000
25	320	140	437,000
24	404	225	556,000
23	509	300	589,000
22	642	370	576,000

Table I is for copper. While the constants B vary, especially as the sizes of the wire become larger, this variation is probably due to possible changes of conditions, such as differences of diameter, length of fuse metal, loads on the generators at the time tests were made and heating of the leading wires as the tests were being made. By averaging B the law for copper wires on 500-volt short-circuits could be stated to be:

$$C = 460,000 d^2,$$

or, expressed directly in terms of circular mils, the current which will flow in copper wires on 500-volt short-circuit will be :

$$C = \frac{C. M.}{1.9},$$

where

C = current in amperes,

$C. M.$ = circular mils.

TABLE II.
ALUMINIUM WIRE.

Size B. & S. Gauge.	C. M. d^2 .	S. C. Amperes.	B
24	404	200	500,000
21	810	290	358,000
20	1021	325	318,000

For aluminium the law for 500-volt short-circuit currents would be :

$$C = 392,000 d^2.$$

$$C = \frac{C. M.}{2.6}.$$

There was one very pronounced peculiarity in the action of aluminium during the short-circuits ; the metal seemed to burn longer and pieces of metal would come down after the explosion, still burning.

TABLE III.
STOCK (LEAD AND TIN) FUSE WIRE.

Size B. & S. Gauge.	Rating Fuse Wire Amperes.	C. M. d^2 .	S. C. Amperes	B
24	1	404	50	125,000
21	3	810	115	156,000
19	5	1252	130	106,000
17	7	2048	230	118,000
15	10	3256	290	86,000

For fuse metal (ordinary commercial lead and tin alloy) the law for 500-volt short-circuit currents would be :

$$C = 118,000 d^2.$$

$$C = \frac{C. M.}{9}.$$

The dense heavy suffocating smoke attending the short-circuiting of lead and tin fuse metals was very pronounced and disagreeable.

Copper gave the best result as regard quantity of current per cross-section of metal. This is shown in the formula for copper

$$C = \frac{C. M.}{1.9}.$$

where compared to the other metals the current per circular mil is a maximum, and that the amount of metal to disintegrate for a given current would be a minimum. In all the tests the behavior of the copper short-circuits were noticeably short and attended with a loud explosive report, with but little comparative flash.

One phenomena was noticeable when a cold surface, such as glass, was placed in the immediate path of the discharge; a finely deposited surface of light copper would present itself. This was unquestionably a case of condensation of the copper gases. While it may be argued that the law as enunciated by the writer, covering 500-volt short-circuit currents through fuse metals may not be rigorously true, still it certainly is as true relatively, as that of the law enunciated by Preece, covering the relation between minimum fusing currents and diameters of fuse metals.

In the use of the law for practical work where fuses had to be employed for cases beyond the values as determined by test, the values as obtained by extrapolation in every instance fulfilled the requirements, demonstrating the practical correctness of the law.

A few cases are cited wherein a knowledge of the law would be of practical value. Take railway work, elevator work, in fact, any case of varying power transmission, where if fuse metals are employed, the size of the fuse metal is governed not so much by the normal safe carrying capacity of the apparatus to be protected, as it is by the expected normal jumps of current the apparatus is designed for, and expected at times to carry. The standard 18 to 20-foot street railway equipments consisting of, say, two No. 3 or No. 14 Westinghouse motors, are usually protected by a piece of No. 14 B. & S. gauge copper wire which will normally fuse under a minimum current of approximately 168 amperes—according to Preece's law—whereas under a 500-volt short-circuit, if not prevented by some foreign means, such as feeder magnetic, or generator magnetic circuit breakers, a flow of approximately 2,000 amperes will ensue. Take as another illustration the lead and the tin alloy fuses employed by

FIG. 2.

the General Electric Company for their G. E. 800 equipments and rated to fuse on 100 amperes, will on a 500-volt short-circuit allow a flow of 3600 amperes for approximately .01 of a second, if not prevented by the opening of the power station magnetic circuit breaker. Further, with this latter type of fuse metal, the quantity of metal to disintegrate is so much greater, that usually more harm is done owing to the vicious character of the gas as regards conductivity, this usually establishing other grounds.

TABLE IV.

L A W.

B. & S. Gauge Copper.	Circular Mils.	PREECE.	HARRINGTON.
		Regular Amperes Rating.	Amperes Short Circuit.
30	100.5	11	39
29	126.7	12	44
28	159.7	14½	62
27	201.5	17	80
26	254.0	20	118
25	320.4	24	140
24	404.0	29	215
23	509.4	34	298
22	642.7	41	340
21	810.1	48	405
20	1021.5	56	510
19	1252.4	67	625
18	1624.3	82	812
17	2048.2	98	1024
16	2582.9	115	1291
15	3256.7	140	1625
14	4106.8	168	2053
13	5178.4	195	2589
12	6529.9	235	3264
11	8234.0	280	4177
10	10381.0	330	5190
9	13094.0	395	6547
8	16509.0	470	8000
7	20816.0	560	10000
6	26250.0	670	13000
5	33102.0	790	16000
4	41742.0	950	20000

At this point it is pertinent to refer to a phenomena accompanying the "blowing" of a fuse on a 500-volt short-circuit; that is, the destructive arcing following the disintegration of the fuse, maintained, of course, at the expense of the terminals. In the determination of the law $C = B d^2$ the after-arcing, was eliminated by using a protected terminal fuse block.

In a paper entitled "The Destructive Arcing of 500-Volt Fuses" read before the American Street Railway Association at Atlanta Ga., October, 1894, by the writer, this matter is elaborated upon, and in brief shows that the results due to arcing, following the blowing of a fuse, may under short-circuit conditions

be far worse than even the results attendant upon the passage of such momentarily great currents.

In Table IV, column 1 gives the size in B. & S. gauge of the copper wires; column 2 gives the circular mils; column 3 gives the minimum fusing current as determined by Preece's law, $C = 10244 d^{\frac{3}{2}}$, and column 4 gives the fusing currents on 500-volt short-circuits as determined by the law, $C = 470,000 d^2$, enunciated by the writer. Fig. 2 graphically illustrates the pronounced disparity of the two laws, showing the curves of currents for diameters: Curve A for Preece's law, and curve B for the law as discovered by the writer. The natural conclusion arising from a knowledge of the above data is that fuse metals are under no circumstances to be considered in the light or nature of a protection.

DISCUSSION.

DR. LEONARD WALDO:—There is one matter that might be commented upon here. Aluminium is coming to play a more and more important part in electrical work, and a word of caution ought to be uttered in regard to the accurate use of the term. If you take a table such as given here, it is of great importance to know just exactly what that aluminium is. Assume that it is commercial aluminium and has a purity of 98 per cent., and that the balance of the ingredients are iron and silicon, which they probably are, and have a resistance about three times as great as that of pure aluminium under the same conditions, while the melting point is only slightly increased. You have, therefore, in questions of fuses, a very marked change in the relations of your aluminium. And aluminium wire that is sold is very often strengthened by the addition of small percentages of copper or nickel, or some of the other metals which are used to give strength to pure aluminium, and those wires pass also in the market under the term "aluminium" wire. I offer this comment as a caution in the use of the term "aluminium," and the use of aluminium wire under such conditions. If Mr. Harrington could furnish an analysis, or in some way define the term "aluminium wire," it would take its place then in terms with copper, which is pretty well understood, and with commercial lead and tin; but even in the case of lead and tin it would be well to indicate the brands, because they vary quite a good deal; and in all questions of resistance, the purity of the metal is of the first consequence.

MR. CHARLES P. STEINMETZ:—In listening to this paper I must confess that I have not quite understood what the writer intends to prove, and, therefore, I beg to be corrected if I am mistaken in my conclusions. But as I understand it, the writer connected