rails is equivalent to about two million circular mills of copper and would require this amount added to shunt one-half of the current. If greater current densities are allowed the current will follow a shunt path through the earth and other underground structures. It may be here stated that the limits of 1 volt per 1,000 ft. is by no means too low, and in congested districts where extensive underground structures are in existence this value may with great advantage be lowered.

In method (*d*), however, since the feeders are only connected to the tracks at its outer end and the negative bar is not connected to the tracks except through the insulated feeders, the voltage drop in them may be any value desirable, without reference to the above-mentioned track voltage gradient or overall difference of potential; and for this reason, the conductor section of the negative feeders can be decided by conditions of economy only. The potential gradients in the tracks depends entirely on the amount of current carried and where this becomes excessive the current is diverted through the feeder.

In a large electric railway system, if this is desirable, the potential gradient need not be entirely in the direction of the station but may be reversed so that the integral of the gradients will give a low value of overall potential differences.

Many railway engineers have claimed that the maintenance of such low voltage gradients as have been specified would require prohibitive expense in copper conductors for heavily loaded street railway systems such as are general on this continent. This is not the case, however. Such claims may be true when method (*c*) is employed; that is, when rails are shunted by the return feeder and the bus connected to ground; but the authors desire to point out that with the insulated return feeder system as outlined above and further described below, such regulation can be easily adhered to at reasonable cost.

The authors thought it would be interesting to the Society to discuss briefly the means by which the modification of the track returns of a street railway system in Canada from method (*c*) to method (*d*) has resulted in a decided reduction of track gradients and overall potential difference, with a consequent disappearance of electrolysis trouble.

Design of the Return System.—The return system of a street railway will be in the form of a network of conductors (the bonded rails) with loads at various points (the cars).

It is only required to consider the negative side of the system since the positive network of trolley wires, mains and feeders has no bearing on the problem with which this paper is concerned. The first step is, therefore, to prepare a plan of the system showing the car position at time of peak load, this data being obtained from the car operating schedules. Average values of current can be apportioned to each car, having due regard to the size of the car equipment and allowance being made for grades and curves, if considered advisable, the whole plan to form a representation of the way the load is distributed over the system.

From data such as that given in appendix A, the resistance of the several parts of the returns can be obtained and the problem becomes a simple power engineering problem of the design of the network to carry the load within the stated limits of potential difference and voltage drop per thousand feet.

The rails form the network of mains and the current from the cars is collected on the network and returned through feeders connected to the station or stations.

It is advantageous at this point to consider the general line of development of a continuous current distributing system for light and power.

A direct current distribution system of small size will naturally take the form of a radial system with feeders run out to the nearest load and continuing therefrom as a main with the loads connected thereto.

The next development will take the form of cross-tie mains connected to the ends of more than one feeder, then further cross mains are installed connecting the outer end of radial mains so that a network is constructed with the radial mains near the station, acting also as feeders to the outer cross-tie main.

In larger systems radial mains cannot feed the outer districts within the desirable voltage regulation limits, and it is necessary either to install additional stations to feed the outer districts or special extra feeders to the outer districts with a means of providing for the extra voltage drop; or, again, the extension of the radial feeders to tap the mains or network at points farther from the station, so that the current from the outer districts is taken from the radial mains at some intermediate point, and the current flows in the main from the nearest loads in a reversed direction.

The choice of method will resolve itself into a question of economics.

It is of special interest to note that in nowise would the alternative expedient of increasing the section of the radial mains be resorted to; as they are normally of large size, a large amount of copper would be required to moderately decrease their resistance, whereas in a feeder having only one point of connection to the load; that is, at the junction to the main, the voltage drop in it can be made any value desirable from consideration of power loss and current-carrying capacity.

All the feeders can be designed with the same voltage drop, or if this requires excessive copper in the longer

Appendix A.—Resistance of Street Railway Track with Electrically Brazed Bonds

Rail size, lbs. per yd.	Rail resistance ohms per ft. without bonds.	1,000 Feet Single Track, 2 Rails Bonded: Res. in ohms with 00 B & S bonds.	Cir. mills equiv. copper section at 25° C.	Amps. for 1 volt per 1,000 ft. gradient.	Res. in ohms. with 0000 B & S bonds.	Cir. mills equiv. copper section at 25° C.	Amps. for 1 volt per 1,000 ft. gradient.
50	20.10×10^{-6}	.01027	1.05×10^{6}	97.5	.01016	1.065×10^{6}	98.5
60	16.65×10^{-6}	.00854	1.265×10^{6}	117.0	.00844	1.28×10^{6}	118.5
70	14.39×10^{-6}	.00741	1.46×10^{6}	135.0	.00731	1.48×10^{6}	137.0
80	12.5×10^{-6}	.00647	1.67×10^{6}	155.0	.00637	1.70×10^{6}	157.0
90	11.36×10^{-6}	.00590	1.83×10^{6}	170.0	.00579	1.87×10^{6}	173.0
100	10.21×10^{-6}	.00532	2.03×10^{6}	188.0	.00522	2.07×10^{6}	192.0