all lamps that this occurs. Some lamps burn better in a building where there is little vibration to joggle the feed and prevent it waiting too long. Again, if a lamp is set to work at a certain voltage, and then you use it at a voltage that is wrong, you get irregularity. Here, for instance, is a lamp of which the record at 40 volts is a most beautiful straight line, there is hardly the slightest irregularity, but the same lamp worked at 52 volts across the terminals is highly irregular. There is a regularly recurrent irregularity in the action of the feed at this higher voltage.

Again another fact Mr. Crompton has observed by following out these records, viz., that if carbons are left in a damp place where moisture can be slowly and regularly imbibed into the pencils, such a carbon, even although of good quality, may give rise to great irregularities. Here is a very irregular record, for instance, obtained from an extremely good carbon, one of Harbuth's make. That same carbon taken out and dried in a stove above steam temperature for two days gives a record which has not a flaw in it. Apparently the warmth of the hot air ascending up from an arc is not sufficient to drive out from a carbon the moisture which has been slowly accumulating in it. It seems to be very necessary, if you would have an arc burn with great regularity, to keep your store of carbons in a dry place.

But this topic does not strictly belong to the optics of the arc; it relates rather to the question of the mechanism of lamps, which is the subject for my next lecture.

THE ELECTRIC DANCING PUPPETS.

UPON a piece of sheet iron forming the cover of a wooden box are placed small figures held erect by means of four supports made of horse hair. As soon as the handle, A, is placed upon the contact, B, there occurs a strong vibration of the plate, the figures move about

THE ELECTRO-DANCERS.

in all directions, seem to engage in conversation, turn around and leave each other only to find themselves together again an instant afterward. From their costume merely it might be thought that they were at an evening party, and from the often regular motions that they execute, that the party was a dancing one. A music box concealed in the apparatus adds to the illusion, and consoles children for remaining alone at home while their parents are amusing themselves at a distance.

The mystery is simple. The battery, P, furnishes a current that passes through the plate and the point, D, whose position for exciting the electric apparatus and giving the vibration the amplitude that the child prefers for his puppets is determined by the screw, C.—La Nature.

THE ELECTROLYTIC ACTION OF RETURN CURRENTS IN ELECTRICAL TRAMWAYS.

By JOHN GRAY, B.Sc., in the Electrical Review.

THE discovery that the earth cannot be safely used for the transmission of large return currents has been one of the unexpected outcomes of the extension of electrical tramways in towns. The gas and water mains, armored cables, etc., in every large town form a network of uninsulated conductors everywhere in contact with the earth, and any current flowing between two points on the earth's surface will be partly carried by these underground conductors. At the surface of contact between the pipe and the earth, where the current enters the pipe, no harm is done; in fact, one would expect that the natural process of corrosion would be arrested or reversed, and the pipe surfaces brightened. But at the surface where the current leaves the pipe, corrosion will be accelerated by an amount proportional to the magnitude of the current leaving the pipes. The activity of this corrosion will depend to a certain extent on the moisture and salts in the soil, but in no case is it likely to be absent.

In the single trolley system, which has hitherto been most extensively adopted for working electrical tramways, the return currents are discharged from the car wheels to the rails, and as these are not insulated from the earth, the earth forms a shunt circuit with the rails returning to the power house, and takes a proportion of the return current depending on their relative conductivities. The amount of stray current carried by the earth and its buried pipes, etc., is by no means inconsiderable; it has been found to amount to as much as 40 to 50 per cent. of the total return current in tramway systems without rail feeders.

An extensive series of experiments has been made by Mr. Stuart Smith* on the gas and water pipes in San Francisco, to determine their potentials relative to each other and to the tramway rails. He found that there was a zone in the neighborhood of the power station where the pipes were positive to the rails, then a short neutral zone, and beyond that a zone—by far the largest—where the pipes were negative to the rails. The resistance of the pipes was found to be made up almost

entirely of the resistance of their joints, the section of metal in the pipes having very little influence. This fact explains the unexpected result that the resistance of the gas pipes was found to be rather less than that of the water pipes; the joints of gas pipes having usually less resistance than those of water pipes. This discovery of Mr. Stuart Smith's, that the resistance of underground gas and water pipes is located almost wholly at their joints, has an important bearing on the remedies proposed for getting rid of electrolytic corrosion. In many of the proposed plans, the current in the pipes is increased instead of being diminished. Evidently, at each high resistance joint a stray current will pass round the joint through the ground, and accelerate corrosion, where it leaves the pipe surface in front of the joint. Unless gas and water pipes have been laid down with joints of good conductivity, any effective scheme for reducing electrolytic corrosion in these pipes must reduce the current flowing in them to a minimum.

Although electrolytic corrosion from electric tramways is much less than sensational newspaper articles would lead us to believe, yet it is going on steadily, and may be expected eventually to cause much trouble. It is advisable, therefore, that steps should be taken from the first to obviate or minimize the damage done to neighboring property.

Mr. Wilkinson, in his "Notes on Electric Tramways in the United States and Canada,"* has given a sketch of the various phases which this question has gone through in practice in America. He says: "As the earth presents an almost infinite mass compared with the rails, it was assumed, in the first instance, that a return of least resistance would be secured by well earthing the negative poles of the dynamos. The coal bill, however, stimulated inquiry into the losses in transmission of electric energy. On many lines of five to ten miles, the voltage at the most distant section between trolley wire and rails was only 50 per cent. of that generated at the station. Some improvement was made by sinking deeper earths into moist soil and connecting the same to more distant points on the rails. But at the best this was unreliable and variable, and it was noticed that improvement was more marked when attention was turned to the rails themselves as the best return conductors." The conductivity of the rails was improved by bridging over the high resistance joints by iron and copper bonds. In the next stage, the rails were connected at intervals to the water and gas pipes, a step which created a satisfactory reduction of resistance in the return circuit, but led to a great increase of electrolytic corrosion and pitting of the gas and water pipes. To mitigate this action, the affected parts of the pipes were connected by cables to the negative poles of the dynamos. This led to the use of a supplementary wire consisting of a bare copper rod, laid between the rails and connected to the rails on each side of the fish plates. But, as this supplementary conductor made no allowance for the increase of the current as the power station was approached, it was considered better to adopt separate return feeders connected to the rails every 500 feet, these feeders being increased in section and number as the lines neared the generating station. These feeders were not insulated, and consequently they were only a partial improvement on the supplementary wire.

Mr. Wilkinson considers that the separate feeder system would completely get rid of the stray currents if they were insulated. He says: "Let the negative poles of the dynamos be connected to the rails direct by insulated cables, but not to the earth at the station, and the current will then be kept within the rails and return feeders. The only chance for current to pass to earth would be as a shunt round bond joints of high resistance or insufficient conductivity; and should this occur, it will only cause electrolytic corrosion at such joints, and not on underground pipes and cables." This view of Mr. Wilkinson's appears to be erroneous. There will still be a current from the pipes to the earth under the end of each feeder where it is connected to the rail. The corrosion will therefore not be got rid of by this plan, but only more widely distributed over the pipes. That, in itself, of course, is an advantage, but something more requires to be done.

Mr. Jenkin, in the discussion on Mr. Wilkinson's paper, pointed out that the only way in which we can completely get rid of stray earth currents when using earthed rails in the circuit is to maintain all parts of the rails at the same potential. This could be perfectly carried out only by using an infinite number of insulated rail feeders, which, of course, is out of the question in practice. Mr. Jenkin calculates that to keep within the Board of Trade limit of 7 volts P.D. between any two points of the rails, the insulated feeders would have to be connected to the rails at points two miles apart; or, if the rails were also utilized to carry part of the return current, at points half a mile apart.

Mr. Jenkin shows that there are two distinct ways in which the potential of the rails can be regulated at the return feeder points: 1. By adjusting the resistance of the return feeders so that they have all the same drop when equally loaded. 2. By working the return feeders at the same density, and therefore with a drop depending directly on their length. In the first case the return feeders are run in parallel at the station off dynamos in parallel; in the second case, the feeders must be run off separate dynamos at different voltages, or some device must be used to vary the voltage. Calculations show that feeders worked on the uniform density principle are the cheapest, but lead to more complicated apparatus in the station than the other system.

This system, though more perfect than Mr. Wilkinson's, does not completely get rid of electrolytic corrosion, since there will always be numerous points near the ends of the feeders where the pipe systems are positive to the rails, and where they will, in consequence, discharge current to the earth. To get over this difficulty, a simple plan has been introduced by Harold P. Brown,† which is considered by Mr. Edison to be the only satisfactory method of preventing electrolytic corrosion in connection with electrical tramways. Mr. Brown's plan is to keep all parts of the

underground pipes at least a few volts below the rails and the surrounding earth. If this is carried out there can, of course, be no current passing anywhere from the pipes to the earth, and consequently no electrolytic corrosion of the pipes. Mr. Brown attains his object by connecting the pipe systems near the power house by an insulated feeder to one of the dynamos with a voltage 12 volts in excess of the normal voltage of the other dynamos whose negative terminals are connected to the nearest point of the rails. This has the effect of keeping the pipes near the power station a few volts below the rails above them, and, of course, puts the potential of pipes still further off, below that of the rails by a greater amount. The drawback to this plan is that it considerably increases the flow of current in the pipes, and thereby increases corrosion at high resistance joints. Mr. Brown obviates this somewhat by prolonging his insulated feeder and connecting it to the rails at their most distant point, whereby the great difference of potential between the rails and the pipes at that point is reduced, and the consequent flow of current through the pipes. Though this system is cheap, and considerably reduces corrosion, there must still be a considerable current in the pipes, and, in view of the results of Stuart Smith's experiments already mentioned, this must always produce considerable corrosion in the course of time at the pipe joints. A combination of Mr. Brown's system with the equipotential rail system proposed by Mr. Jenkin would lead to an improvement on both systems, as only the comparatively small stray currents between the feeder ends would be collected in the pipes, and harmlessly drawn off by Mr. Brown's clamp and insulated feeder.

By such devices, there can be no doubt that electrolytic corrosion of pipes, if not completely eliminated, can be very much reduced. Whether the steady action of these reduced stray currents for many years will increase the natural rate of corrosion of pipes, etc., to such an extent as will give the companies concerned a claim for damages, remains to be seen. Up to the present there is no sufficient evidence that this is the case. The legal decisions, such as that in the case of the telephone company and the Leeds Corporation, appear to protect the tramway companies, provided they adopt the best means known for preventing damage by earth currents. If future developments should induce either the Board of Trade or the courts to demand the entire suppression of stray currents, electrical tramway companies can always fall back on the double trolley system, or some similar system in which no part of the circuit is in connection with earth.

THE SINGING ELECTRIC BELL.

THREE centuries ago the father of Montaigne, desiring to spare his son's nerves, had him awakened to the sound of soft music, and yet our ancestors of that epoch were far from the deplorable state into which modern life has put the nervous systems of most of us.

THE SINGING ELECTRIC BELL.

An unexpected and strident noise irritates us, an electric bell or a telephone call sometimes makes us start, and there is no one who has not more than once desired a less atrocious method of attracting his attention.

The inventor of the apparatus that we are about to describe, Mr. Guerre, an electrician, of Paris, has solved the problem in the simplest and most elegant manner. For the bell with a hammer and a spring interrupter, he substitutes a steel bell which is its own interrupter. An electro-magnet, A (No. 1 of the figure), is placed in the interior of the bell, T, in such a way that its extremities come into immediate proximity with its wall. A small platinum point, P, fixed to a block of ebonite, C, leads the current to the bell, which transmits it to the rod to which it is fixed. Thence, the circuit continues through the bobbin and returns to the battery.

If the circuit be closed, the edge of the bell is immediately attracted and its support bends slightly, while, at the same time, the bell itself curves in closing. The contact is interrupted and the system returns to its starting point, and so on until the vibrations of the bell have reached an amplitude sufficient to produce a free interruption of themselves. The rod then ceases to be concerned in the vibration, and the bell alone continues to vibrate under the action of the electro-magnet in giving a continuous musical sound quite similar to that obtained by rubbing the edge of a glass with the finger. The regulation of the interrupter is naturally the essential condition for the proper operation of the apparatus. In order to render this possible, the block of ebonite, C, is carried by a stiff spring, the position of which is fixed by means of a very firm screw so as to obtain a maximum of action of the bell. No. 2 of the figure represents the apparatus in its sounding box.—La Nature.

* Journal Inst. Elec. Engs., vol. 23, p. 631.

† Electrical Review, April 19, 1895.

* Electrical World, vol. 35, No. 12.