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ELECTRIC RAILWAYS.

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[*A Lecture delivered before the FRANKLIN INSTITUTE, February 10, 1890.*]

The Speaker was introduced by Prof. EDWIN J. HOUSTON, of the INSTITUTE, and spoke as follows:

MEMBERS OF THE INSTITUTE, LADIES AND GENTLEMEN:

Street railways are the arteries of our great cities; the suburbs and parks are the lungs; the business centre is the heart. The arteries radiate from the heart with numerous and winding ramifications through the entire system. The blood is purified and rejuvenated through the lungs. The ebb and flow of traffic is an exact indication of the healthy condition of the city as the ebb and flow of the blood is of the body. Choke an artery and stagnation results. Cut it off entirely and the part no longer supplied mortifies and

dies. A new artery, reaching to a new part, means new life and new growth.

The simile is not exaggerated. Few appreciate the vital part played by our street railway transportation system in the daily routine of our great cities. Such a forcible lesson as the New York strike of 1888 awakens temporary reflection, but is soon forgotten. Street cars are so common that we avail ourselves of the benefits they confer without consideration of the means by which these benefits are made available. The study of statistics, however, discloses many facts that are interesting, instructive and astonishing, as to the dependence of the public upon street cars, and the close connection between their efficient service and the wealth, health, growth and comfort of the city.

Many of you are probably not aware of the fact that the cars of Philadelphia alone carry nearly fifty million more passengers per year than all the steam roads of the great state of Pennsylvania. A few statistics of this nature are more impressive than pages of rhetoric.

During the year ending September 30, 1888, the 108 street railways in the state of New York carried 554,266,682 passengers, or 100 times the total population. If the ratio was even approximately the same in other states, there must have been carried by the street railways of the United States, during that year, not less than four billion passengers.

In New York City, the surface and elevated roads carried 371,021,524 passengers, or 247 times the population. In 1855, with a population of 620,810, New York City furnished 18,488,459 passengers, only twenty-nine times the population. The gain in ratio of passengers to population has been uniform from 1855 to 1888, being forty-five in 1860; 122 in 1870; 175 in 1880; 225 in 1885; and 247 in 1888.

The same increase is noticeable in other cities. The population of Boston in 1870 was 250,256. The street railways, with 346 cars, carried 23,176,167 passengers. In 1888, with 1,584 cars, the roads carried 97,039,919 passengers. The ratio of passengers to population increased in eighteen years from ninety-three to 215, and the ratio of passengers to cars diminished from 64,090 to 61,262.

The Philadelphia roads carried 143,443,959 passengers in 1888, or 137 times the population.

In Massachusetts, the street railways carried fifty per cent. more passengers than the steam roads. In Pennsylvania, the ratio was 2 to 1. In New York State $5\frac{1}{4}$ to 1. These figures lead to several important conclusions:

(1) Our street railways carry approximately twice as many passengers as the steam roads.

(2) The number of passengers increases much faster than the population, which means that more people ride, and ride more frequently each year.

The transportation of upwards of four billion passengers yearly with safety, speed, comfort and economy, is a gigantic task, and the means by which it is accomplished are well worthy of careful investigation. There is perhaps no line of work for the inventor and the engineer in which improvements are of more direct benefit to the masses than street-car propulsion.

At present we have five well-known methods of municipal transit; horse cars, cable cars, steam dummies, elevated roads with steam locomotives, and electric roads. Each is valuable in its way and each has been of great utility to the public at large. There are many well-known objections to the first four methods, which it is believed electricity will obviate.

The electric railway, as usually constructed, may be briefly described as consisting of a power station, where the dynamos generate electricity, which is carried by an overhead wire out over the tracks, thence by means of the trolley arm on top of each car down through the motors under the car, through the wheels, and so to the rails, and back through the rails to the dynamos at the power station thus completing the circuit. The electric current causes the motor armatures to revolve, and the armatures, being geared to the car axles, move the car. The driver stops the car by breaking the electric circuit, and reverses by reversing the direction of the current through the motors.

I have no intention of entering into any detailed history of the development of the electric motor and its application

to street-car propulsion. There are, however, a few epochs in this development which it may be of interest to note.

In 1834, Jacobi, a Russian physicist, produced rotary motion by means of an electro-magnet. In July of the same year, Thomas Davenport, a blacksmith, of Brandon, Vt., completed and exhibited an electric motor.

In 1851, Prof. Page, of the Smithsonian Institute, made a trial trip with an electro-magnetic locomotive on the Baltimore and Ohio Railroad from Washington to Bladensburg.

In 1864, Pacinotti first announced the principle of the reversibility of the electric dynamo.

In 1873, the Gramme Company made a practical demonstration of this principle at the Vienna Exhibition. Since this date, electric railways have been among the possibilities; before this, the cost of zinc as a fuel made them impracticable.

In 1879, Dr. Werner Siemens constructed and operated an exhibition railway at the Industrial Exhibition at Berlin. A third rail centrally placed between the other two was used as the outgoing conductor.

In 1881, the first commercial railway was put in operation in the suburbs of Berlin—the Lichterfelde Line. It is a mile and a half long with a gauge of three feet three inches. The rails are laid on insulated sleepers, one used for the outgoing and one for the return circuit. This method of construction puts it without the pale of practicability for ordinary tram-car work.

In the same year, 1881, the first overhead line was built. This was an experimental road at the Paris Electrical Exhibition. The conductors were suspended hollow tubes with longitudinal slits. Contact was obtained by metallic bolts drawn through the tubes by wires attached to the cars.

In February, 1883, the Van Depoele system was exhibited on a short road in Chicago. The use of an overhead wire was contemplated, but the ground being frozen the wire was strung beneath the cars and kept from the ground by boards with V-shaped tops placed at frequent intervals. The

rails were used for the return current. This exhibition plant was run every day for several weeks with complete success, carrying crowds of people.

In November, 1883, the celebrated Portrush Railway in the North of Ireland was put in operation. On this road, the conductor is an insulated rail placed on uprights alongside the track.

In November, 1883, the Daft Motor "Ampère" was tried experimentally on the Mt. McGregor and Lake George Railroad at Saratoga Springs.

In 1884, the Bentley-Knight conduit system was tested on the East Cleveland Road, at Cleveland, O., and the Van Depoele conduit system at the Toronto Exhibition.

In 1885, the road at Blackpool, England, was formally opened. This is operated by the conduit system.

Storage battery cars were exhibited as early as 1881 at the Paris Exposition. In 1882, a line was put in operation at Breuil-en-Auge, France, using Faure batteries. Storage cars have also been tried at Brussels and other places abroad. The only road actually operating storage batteries in this country, is the Fourth Avenue Line, New York City. This road has had as many as ten cars in service. At present but one is running.

In the summer of 1886, the Sprague Company began the installation of the Richmond Road. This road was in full operation in the spring of 1887. On July 4th of the same year (1887), the first Thomson-Houston car was started on the line at Crescent Beach, Mass.

ELECTRIC RAILWAYS IN THE UNITED STATES AND CANADA.

	JANUARY 1, 1890.						Total in operation and under contract.	Total in operation.	Total under contract.
	1885	1886	1887	1888	1889				
Number of electric railways put in operation each year,	3	5	7	33	104	251	137	114	
Number of miles of road, . .	7.5	28	29	130.5	641	1641.75	771.5	870.25	
Number of cars,	13	39	81	265	965	2346	1230	1116	

The development of electric railways in this country is shown by the foregoing statistics :

January 1, 1890, shows an average of about six miles and nine cars for each road.

Considering the electric road from a scientific standpoint, we note :

- (1) The generating station.
- (2) The car equipment.
- (3) The line.
- (4) Storage batteries.

THE GENERATING STATION.

Location.—One of the great advantages of electricity as a motive-power is the possibility and practicability of placing the power station in the most convenient location. If by going several miles into the country, we can secure cheap water-power, we do so, as the loss in transmission is inconsiderable—nothing in comparison with the possible reduction in first cost. Or we can go to the water-side where compound condensing engines can be used, cutting down the coal consumption to two pounds of coal per horse-power-hour, or even less. Or we can go to the side of the railroad track where coal can be delivered without cartage at the lowest possible cost. We may combine many of these advantages and we are free to seek them all.

Power Plant.—To determine the best form of wheel with water-power, or steam plant with coal, are engineering problems which many are ready and able to solve. We must recognize the fact, however, that street-car work imposes a very variable load on the engines and dynamos and the fluctuations are sudden and violent. We require stronger engines than are needed for constant loads.

Dynamo.—The ordinary form of incandescent dynamo is used. The latest type of machine developed by the Thomson-Houston Company is a 100 horse-power four-pole compound-wound dynamo. This machine shows an electrical efficiency of over ninety-five per cent. The perfection of the regulation of the series coils is practically shown in an eighty horse-power machine at the electric-lighting station

at Lynn, Mass. A single motor car on the Highland Circuit Line is run from this dynamo. The circuit is about 1.7 miles long with eleven curves and grades ranging up to ten, twelve, thirteen and fourteen per cent. One grade, 750 feet long, averages thirteen per cent. with a short stretch of fourteen per cent. near the middle. The car usually descends this grade, but has a long grade of ten per cent. to ascend. To test the power of the motors it is a common occurrence to stop the car, even when heavily loaded, on the steepest grade, and then reverse the motors and back up the hill. It has been noted that with a full load on the car an instantaneous effort of about eighty horse-power at the station has been required to start the car back up the fourteen per cent. grade. The sudden change of load from 0 to 80 horse-power probably imposes as severe conditions upon this generator as upon any in use in this or any other country. The generator was carefully tested while the car was making two or three round trips, and the greatest fluctuation observed was two volts. One is unable to distinguish any difference in the action of the dynamo when the load is on and when running free. The engine, however, speaks forcibly at times.

The rapid development of railway work calls for larger stations and larger generators. The Thomson-Houston Company is now building 250 horse-power machines of the same four-pole type as the 100 horse-power. It is probable that even larger machines will be required in the near future. Carbon brushes are used with these generators, having many advantages over copper. The wear on the commutator is reduced to a minimum of trifling consideration and the surface is kept smooth and polished. The use of carbon brushes and the perfection of the compounding are of vital importance where machines are subjected to the violent fluctuations of load inseparable from railway work. It is interesting to note in this connection that Prof. Thomson is now developing a simple arrangement to modify these fluctuations, which will be of great value in reducing the strains on the generator and motors in starting, and incidentally by reducing the electric waves in the lines, to

diminish the inductive effect on neighboring wires. The recent types of dynamos are provided with self-oiling boxes and require very little care or attention while running. So far as can be determined, the durability of these machines is equal to that of the best lighting machines, which is certainly all we can desire.

Voltage.—For the economical transmission of power a high voltage is desirable. For practical reasons, the voltage must be kept within limits perfectly safe as regards danger to life in case of accidental contact. Five hundred volts has been universally adopted as the maximum limit for railway work, this being as high as we can go and still keep well within the limit of safety.

Current.—Up to the present time no form of alternating motor has been devised suitable for railway work, or at least, no practical results in this direction have been made public. Direct currents alone have been used.

Station Equipments.—Each dynamo is provided with an ampère-metre and a circuit-breaker. The station is also supplied with volt metres. The circuit-breaker is adjusted to the ultimate safe limit of current, and is intended as a last resource in case of short-circuit, or over-load to save the armature, the engine or the belt, whichever may happen to be the weakest. When the electric railway was started at Washington in October, 1887, the generator was not provided with a circuit-breaker. In laying the floor of the power station, the carpenter accidentally overturned the incompleted switch-board which was leaning against the wall, resulting in a short-circuit of the dynamo through about eight feet of double-nought wire. Neither the armature nor the belt yielded, but the 100 horse-power engine was stopped. It was several hours before the carpenter could be induced to resume work.

We are now developing a method of automatically preventing any increase of load on the dynamos beyond their maximum capacity. This will do away with circuit-breakers and will be of immense advantage in many ways in the operation of cars. If the railway Superintendent attempts to run cars beyond his power capacity, the result will be, not

to throw the circuit-breakers and stop the whole line for an instant, but simply to reduce the potential or quantity of the current *per car*, and so reduce the speed. The generators will automatically respond to all demands for power, as they do now, until the maximum is reached; but they will absolutely refuse to go beyond this point.

THE CAR EQUIPMENT.

Motors.—The motors in general use have series-wound Siemens armatures. The advantages of the Gramme ring, such as simplicity in repairs and better ventilation for heated armatures, are fully recognized, but the disadvantage of large armatures is a serious one, as the space available beneath the car is limited and the motor must be made very compact, especially in its vertical dimensions. The use of larger car wheels may permit of a change in this respect.

Regulation.—On the question of regulation the various electrical companies do not agree. From a scientific standpoint, the commutated field appears desirable, but there are many practical and commercial reasons in favor of the outside resistance or rheostat. The commercial results of the various roads operating with these two methods of regulation will probably determine in time which is the better, all things being considered. Regulation without commutated fields and without a rheostat would seem to be preferable to either of these methods. Such a system has been devised and is about to be tested in Boston.

Efficiency.—The motors now in use have shown by careful test an efficiency as high as $91\frac{1}{2}$ per cent. The commercial efficiency will, of course, run below this figure.

Location of the Motors on the Car.—The best location of the motor has been, and is still, a disputed question. If the objections are not too serious, I think all will admit that the best position is under the cars, as is now the common practice. The objections are: The difficulty of getting at the motors for repairs, adjustment and cleaning; the fact that being near the ground they are exposed to water, mud, sand, dust, etc.; and that in such position they run without observation, and a slight accident, not being noticed, may result

in considerable pecuniary damage, when, if noticed, it could probably be remedied with but little cost or trouble. We must, and we do, make motors that will run with few repairs and adjustments, and pits or raised tracks should be provided at the car-houses, where the machinery can be cleaned, repaired and adjusted. The practice on some roads of giving the motors a more or less thorough inspection at the end of each round trip is an excellent one and is commended to all railway managers. Thorough and constant inspection is economy in the end, and the good result of this method is shown on one road, where, with ten cars in operation, two months will elapse without a single car being taken to the car-house for repairs.

The exposed position of the motors under the cars is a serious objection. They are usually protected by a sheet-iron pan hung beneath them, and by canvas screens on the sides and ends, and the results seem to show that such protection is sufficient to secure good commercial results. The third objection is a good one. It would undoubtedly be better to have the motor run in full view, but we must remember that the average street-car driver knows but little about electric motors and recognizes the fact that something is out of order only when the motor refuses to work and the car fails to run. Unless a higher grade of men be employed as drivers, the advantage of bringing the motor under their direct observation would be slight.

The use of a separate motor car to haul one or more ordinary cars has been considered; the locomotive to have the motors placed above the floor. There are many advantages in having each car carry its own power, but it is possible that some form of open car similar to the grip car on cable lines may be found practicable, the electrical apparatus being better protected and being more accessible. One great advantage would result from a change in the present method of hanging the motors directly on the axles, that is the possibility of securing better insulation. One serious difficulty would be encountered, that is the question of gearing.

Gearing.—The question of gearing is all-important. The

great majority of roads at the present time are using direct gearing, with one motor to each axle. The wear on the pinions and gears is not excessive, but is a matter for consideration from an economical standpoint. While the noise made by the electric car is not serious, it is of great advantage to reduce it to a minimum, and this is largely a question of gearing. The large intermediate and axle gears are iron with cut teeth. The pinions are either solid or built up. We are now using laminated steel and rawhide pinions, laminated steel alone, solid steel, gun metal, phosphor-bronze and rawhide. Rawhide seems to possess sufficient strength and is practically noiseless. Alternations of wet and dry weather, and extremes of temperature are, however, disastrous, and its use will probably be restricted to equable climates. Laminated steel and rawhide has been largely used, but the advantages of the rawhide do not compensate for the extra expense. Solid and laminated steel give good results—the latter being cheaper and causing less noise, as the ringing sound is broken up. Gun metal is giving excellent results; it makes little noise; the wear on the gear is almost nothing; it is not expensive and when worn out can be sold for old metal at a reasonable proportion of the original cost. It wears faster than some of the other forms, but we can afford to replace it more frequently.

Other methods of gearing have been tried and we have by no means abandoned the attempt to improve upon the present system. The worm gearing, used by Mr. Wharton on his storage battery cars, has given excellent results. It is to be regretted that no exhaustive tests have yet been made as to its efficiency, but this lack of information will soon be remedied. The bearings of the worm are phosphor-bronze and the worm itself is made with a sharp pitch. It is very durable and the wear is slight. It turns readily in either direction and if it shows a proper efficiency, it certainly is worthy of a very extended and thorough trial. Most engineers would probably be prejudiced against this form of gearing, but the ease with which two men can push one of Mr. Wharton's cars is certainly astonishing.

Friction gearing has been suggested, but up to the present time I have seen no practical form. The rapid rotation of the armature, running at times up to 1,500 revolutions a minute and even higher, and the severity of the sudden strains to be applied must not be lost sight of. The conditions are very different from those encountered with a factory shaft. We are now testing a new form of friction gearing which promises good results, and it is expected that something of value in this direction will be developed during the year. If the friction on the rail is sufficient to move the car, there is no good reason why the same principle should not be applied primarily to move the axle.

Sprocket chain gearing has been used, but has been generally condemned. It may be found useful in connecting the two axles, where a single motor is used, as the strain in such cases would be slight and the wear correspondingly diminished. Rope gearing may be found useful in the same way.

We have now working in the Scranton coal mines, an electric locomotive, in which the motor is geared to an intermediate shaft carrying a wheel connected with the two car wheels by ordinary connecting rods. This method has given good results and may be susceptible of further extension.

Trolley.—The trolley arm and trolley wheel, where the overhead system is used, are important elements in the successful operation of the system. All agree that the upward pressing contact is the most feasible, if not the only practicable method. Springs at the lower end of the trolley arm keep the wheel firmly pressed against the under side of the trolley wire. The arm should combine lightness, strength and flexibility. We are using various forms of solid and built up steel, steel tubes, wood and steel, and wood alone. Split hickory with a steel rod in the centre gives very good results.

The trolley wheel is an important detail of the system and care and skill are required in providing for its rapid rotation, for good contact, for durability, and for certainty of operation.

THE LINE.

The conductor may be overhead or underground.

Conduits.—The conduit systems so far have been failures, except when operated under exceptionally favorable conditions. I doubt if any form of open-slot conduit can be devised to meet satisfactorily all the conditions under which tram-cars are operated in this country. Inventors are working on various kinds of closed conduits and we may hope that some practicable system will be ultimately developed, but at present there is little to encourage us in this direction.

Double or Single Wire.—With the overhead system, the first question which arises is, shall double or single wires be used; shall we have a ground return or a complete overhead metallic system? While the double wire is unquestionably feasible on small roads with few or no curves, no crossovers, turnouts or switches, it is certainly impracticable on any complicated system. It is sufficiently difficult to adjust the frogs, crossings, etc., for a single wire, so that the trolley will automatically follow the car; if we attempt to duplicate these parts with another wire and to insulate the two wires for a 500-volt current, the difficulties are increased to such an extent that they cannot satisfactorily be overcome. The most ardent advocate of the double-wire system has only to look at the crossing of Boylston and Tremont Streets in Boston, or Park or Scolley Square, to have his faith shaken. One has but to draw a diagram of such crossings or even of an ordinary Y, showing the positive and negative wires, to realize the extreme, if not insurmountable, obstacles to such a system. The addition of a second trolley to each car would not be one of the least difficulties. With the single trolley system, the rails, the tie wires and the supplementary wires constitute a metallic return, so that we actually have a complete metallic circuit though but one wire is overhead.

Kind and Size of Wire.—Copper wire is the best on the score of conductivity. Steel would be preferable for strength. Silicon-bronze is frequently used. The larger the wire, the greater the strength and the better the

conductivity; but increase in size entails the disadvantages of greater unsightliness and greater weight. The trolley will work better against a large and heavy wire, but such wire brings increased strains on the poles and cross-wires. The proper mean is not easy to determine, but few roads have been constructed with the trolley wire larger than single-nought B. & S. gauge.

The unsightliness of the wire is a consideration more theoretical than practical; few would notice the difference between No. 0 wire and No. 4 wire when in place.

The wire is supported over the track by cross-wires between two lines of poles, or by bracket arms from one line of poles, where the track is sufficiently near the curb. Various forms of insulating and suspending devices are employed, but the limits of this paper will not permit of any description of details.

The centre-pole system, where the poles are placed between the two tracks, is undoubtedly the best when the street is sufficiently broad to permit its use. The tracks should be separated by a space of six or six and one-half feet. The poles being subjected to a vertical strain only, need not be as strong as side poles, and the whole construction can be made neater, stronger and in many cases cheaper. The Eckington and Soldiers' Home Railway on New York Avenue, in Washington, is constructed with centre poles. The Commissioners of the District of Columbia say of this road: "Of the overhead systems now employed, the Commissioners believe that the one used by the Eckington and Soldiers' Home Railway Company, in which the conductors are supported by poles situated in the middle of the street, is the most satisfactory where there is sufficient width of carriage-way for its employment." An experience of sixteen months has shown that these poles are no obstruction to traffic. No accident has resulted from their location between the tracks.

The District Committees of the Senate and of the House of Representatives have in official reports repeatedly pronounced this road to be the finest in the United States and the centre-pole method of construction is not the least of its

attractions from this official standpoint. Unfortunately in most cities there are few avenues on which such a system is practicable.

The overhead line is one of the most important parts of an electrical installation and no pains should be spared to make it perfect. Do not try to economize on the overhead line. Give it a good margin of safety as regards strength and make it as ornamental as possible.

Feeder Wires.—The trolley wire carries a limited quantity of electricity, proportional to its size and conductivity. When the length of the line or the number of cars running, or the steepness of the grades requires power in excess of the capacity of the trolley wire, feeders are used, running from the station to various points of the trolley wire where re-enforcement is needed. These feeder wires need not of necessity be carried on the same poles or even on the same street as the trolley wire. They may be placed underground, if necessary.

With double trolley wires, a double feeder system is necessary.

Rail Return.—With the single trolley system, the rails are utilized for the return current and each joint is bridged by a tie wire to reduce the resistance and prevent the wandering of the current through the earth. Supplementary wires are also run underground and attached to each tie wire for the same reasons.

Guard Wires.—Where many telephone, telegraph and other lines cross the trolley wires, guard wires should be used to prevent such wires from falling upon the live trolley wires. It is probable that in course of time municipal regulations will be enacted, compelling the telegraph, telephone and other companies to so construct their lines as to make them safe, as has already been done in some instances, but until such action is taken, the railway companies should provide such safe-guards as can be readily constructed. Guard wires generally consist of steel wires stretched parallel to and above the trolley wires. The guard wires may be bare or insulated, but in either case they should be carefully insulated from the trolley wires. On the double track roads

in Boston we use three guard wires, one about fourteen inches above and fourteen inches outside of each trolley wire, and one midway between the other two. These guard wires are suspended from a second span wire above the first and are insulated from the second span wire. With such construction, the chance of a falling wire coming in contact with the trolley wire are so remote that it may be neglected and we may regard the guard wires, when properly maintained, as affording the needed protection.

STORAGE BATTERIES.

But little has been done on any extended scale in the practical application of storage batteries to street-car propulsion. Mr. Wharton has demonstrated the possibilities in this direction, and the Julien Company has shown cars in actual operation in New York City. The chaotic condition of the storage battery patents has been responsible to some extent for this condition of affairs. When the atmosphere has been cleared and the various companies realize their exact position on the patent question we may hope for more active developments. At best, however, the storage battery will always be at a disadvantage in comparison with the direct method. It will probably be more expensive and the supply of power on each car being limited, we are in no condition to encounter unusual resistances. Storage battery cars could never have battled with the snow and ice as the motor cars have had to do this winter in Scranton, Minneapolis, Omaha, Council Bluffs, St. Louis, Kansas City, Wichita, and elsewhere.

Considering the electric railway from a commercial standpoint there are five points for primary investigation:

- (1) Its feasibility.
- (2) Its economy.
- (3) Its durability.
- (4) Its reliability.
- (5) Its first cost.

FEASIBILITY.

By feasibility I mean: Are there any reasons why the public should object to the introduction of electric railways and the municipal authorities refuse to grant the necessary rights? Is it dangerous?

The public have been unnecessarily alarmed as to the dangers of electric wires—lighting as well as railway. No one denies the fact that the arc lighting current is, or may become dangerous to life: but if surrounded by proper safe-guards, if constructed and maintained in accordance with proper rules and regulations, the danger is so slight that I think you will be astonished at the actual figures.

During the past year the deaths from violence in New York City, aggregated 1,467. Of these, 265 resulted from falls; blows from falling objects, thirty-six; run over by horse cars, twelve; run over by cars and engines, thirty-three; run over by wagons and trucks, thirty-two; asphyxiated by gas, twelve; and killed by electricity nine. Yet in New York City the fear of overhead wires has during the past year been aggravated to a most alarming degree.

During the year covered by the last report of the Board of Health, the total number of deaths in Boston from casualties aggregated 399. The railroads were responsible for seventy-eight; sixty were drowned; thirteen were run over by vehicles; nine were killed by elevators; twelve died of the effects of heat, and no less than seventy-eight were killed by simply falling down, of whom sixteen fell down stairs, seven fell on the sidewalk, six fell from buildings, five fell from teams, four fell on the ice, one fell from a chair, one fell from a tree, one fell from a bicycle, one fell from a fence, and so on. Not a single death is recorded against electricity. There are in New England 131 arc-light central stations, which have been in operation from one to ten years, burning over 20,000 arc lamps and distributing thousands of horse-power by wires through and over all the principal cities and towns. During this period there have been but five deaths from electricity. What other industry, comparable with the electric industry, can show such a

record for safety? During these ten years, the steam roads of New England have killed and injured no less than 5,241 human beings. Of the five deaths by electricity, four were employés of the lighting companies and one only can be classed with the public. Of those killed or injured by railroad accidents, 2,339 were employés and 2,902 were general public. Not only is electrical energy shown to be absolutely safer than any similar quantity of energy used in other industries, but in most cases it is relatively safer, as even the few deaths that do occur are among the employés and in general, are caused by neglect of instructions and failure to observe the necessary precautions.

Another objection urged against electricity is the danger of fires. It is common now to attribute every fire to electric wires when the cause is not clearly apparent. Let us examine the statistics on this point for the past few years.

Since the establishment of the office of Fire Marshal in Boston, its present incumbent has investigated in the most thorough manner every fire, and has given us a record as to causes probably as complete as it is possible to obtain. From November 8, 1886, to May 1, 1887, 344 fires were investigated, of which only five are returned as "cause unknown." The kerosene lamp caused thirty-two; rats and matches are responsible for eleven; dropping of matches, twenty-seven; children and matches, thirteen; careless use of matches, twelve; overheated stove, sixteen; hot ashes from tobacco pipe, ten; lighted cigar stumps, six; sparks from locomotive, three, and electric wires, three. Electricity caused .009 of the fires. For 1888, we find the same record for kerosene, matches and rats and matches, while electric wires are responsible for only .007 of the fires. In the 1889 report, sparks or heat from furnaces, locomotives, steam-pipes, etc., are responsible for fourteen per cent. of all the fires; kerosene stands well up with thirteen per cent., while matches in conjunction with men, rats and children, are responsible for twenty per cent. of all the fires. Electricity comes in with a modest two per cent., being on a par with hot ashes, and twice as harmless as fire-crackers and fire-works.

It would seem that such a record should exonerate the electric wires from the charges brought against them.

The above refers to electric wires in general. Now a few words as to the electric railway wires.

While the arc light wires carry currents of from 2,000 to 6,000 volts, the railway wires carry a current of only 500 volts. This voltage is fixed, and the quantity of electricity varies according to the needs, *i. e.*, according to the number of cars running.

It is an incontestable fact that no man, woman or child has ever been killed, or even seriously injured, by a 500-volt current, though many have been subjected to the shock. Every alleged case of death or injury by railway wires has, upon investigation, been shown to be without foundation, or else to have been caused by the arc current. As illustrating this point, I might cite the case of the colored boy said to have been killed by the railway wires at Chattanooga. He was found in a pit beneath the car he had been employed to clean, with his clothing on fire and an overturned oil lamp between his legs. He burned to death. This occurred in the night, an hour and a half after the road had ceased running and the power station had shut down. There was no current in the wires, and had been none for an hour and a half, yet this death has been repeatedly ascribed to railway wires. While hundreds have taken the full 500-volt current, no one, not even a child who held a contact wire for four minutes, has ever been seriously injured.

In the report of the Commissioners of the District of Columbia on the Eckington Railway, from which I have heretofore quoted, they state: "The Commissioners believe that the electrical system employed by this railway, the electro-motive force of which can never exceed 500 volts, is as safe as any motive system ever employed by any railway. The Eckington Railway has never had any accident whatever resulting from its employment of electric motive-power, and the Commissioners believe this to be also true of all other electric railways now in operation throughout the United States."

As to danger of fire, since the railway wires enter no buildings, they cannot of themselves cause fires. The current might be conveyed through some other circuit by wires falling on the trolley wires. Without discussing the law and equity of requiring such wires, when they cross the streets or cross other wires, to be so put up that they will be safe, it suffices to say that by the use of guard wires we prevent falling wires from coming in contact with the trolley wire, and the chance of a railway wire causing a fire, either directly or indirectly, is so remote that it will probably not be found worthy of a separate classification in the list of "causes." Every electric wire entering a building should be provided with a fuse or a short-circuiting device, so that stray currents of greater voltage or quantity than the normal will be effectually cut off.

Increased speed does not necessarily mean increased danger to other vehicles, pedestrians or to those who ride or drive. In the city of Pittsburgh, Pa., is a cable road, on a heavily-travelled street, only thirty-six feet wide, in the heart of the city. A double-track road on this street leaves about nine feet between the outer rail and the curb on each side. Formerly the cars were run at the rate of seven miles per hour; some time ago the speed was increased to nine and one-half miles per hour. The records show that there are actually fewer accidents with the present speed than with the former, and this for a period that establishes the accuracy of the statistics. The result is easily accounted for. Pedestrians and drivers of vehicles take great care to avoid the fast-running car, while they are more or less careless and indifferent when the speed is slow.

ECONOMY.

Even were electricity as expensive as horse-power, its numerous advantages would ultimately result in its general adoption, but as a matter of fact, it shows a very considerable saving over horse-power. This is to be expected. If we have one source of power—one power station—instead of a thousand, we ought to generate the power at a less cost. If we have efficient motors and a well-constructed

line, we should expect to utilize this power with little waste. Of 100 horse-power produced in the steam-engine, ninety-two is converted into electricity and goes out of the station over the line as electrical energy. The loss in the line need not exceed ten per cent., though in some cases it may be economy to allow a larger loss. We thus have 82·8 horse-power delivered to the motor on the car. If the commercial efficiency of the motors and gearing be seventy-five per cent., we have 62·1 per cent. horse-power utilized in moving the car; or a total efficiency of 62·1 per cent. Of course, we may fall below this figure. The actual power required per car depends upon the grades, the speed, the curves, the kind and condition of track, the size and weight of the car, the average load, etc., conditions so variable that it is hopeless to try to determine any average figure. The power will range from four horse-power to nine horse-power under ordinary conditions, and may increase very considerably under extraordinarily bad conditions. The cost of power at the station depends upon the kind and size of the engines, the price of coal, the management of the station, etc. It ranges as low as nine-tenths of one cent per car mile, and as high as seven cents per car mile. The latter is a very extreme case and does not represent the actual cost. This price is paid for power for a single car operated under the most disadvantageous conditions; this car, however, yields a better return to the railway company than any other car on its entire system. This indicates that a high price is not always incompatible with economical results. The cost of repairs depends very largely upon the care bestowed upon the apparatus, and any figures given without a full statement of all the special conditions would be misleading. I have known the cost of material for repairs on a large road to run as low as nine mills per car mile for one month, and I have known it to go very much higher.

Speed is not only an important factor in determining the value of electric railways to the public, but it is equally important to the railway manager as a source of economy. If we average six miles per hour with horses and nine miles

per hour with electricity, it is evident that in the latter case one car does fifty per cent. more work with a corresponding saving in the item of wages of conductors and drivers.

In the crowded city streets we cannot hope to gain much speed. In the suburbs the gain is only limited by considerations of safety. From Harvard Square, in Cambridge, to the end of the line, in Arlington, the electric cars average about eleven miles per hour, including stops—better time than is made by the elevated roads in New York City. On the Watervliet Road, between Albany and Troy, the following is the record of one month's work:

MILEAGE OF WATERVLIET CARS, DECEMBER, 1889.

Average number of cars in daily service,	7¼
Total mileage, thirty-one days,	31,340
Average daily mileage,	1,011
Average daily mileage, per car,	139

On December 20, 1889, we have the following record of five cars:

	Miles.
Car No. 43 made a total of,	180
" 44 " "	190
" 45 " "	190
" 46 " "	190
" 61 " "	180
Grand total,	930
Average per car,	186

On January 3, 1890, we have the following record of five cars:

	Miles.
Car No. 40 made a total of,	190
" 42 " "	190
" 44 " "	190
" 60 " "	180
" 62 " "	180
Grand total,	930
Average per car,	186

This is an imposition upon the motors. It is requiring more than we ask of the steam locomotive which runs under the most favorable conditions as to grades, curves and

track. I give these figures as an instance of what can be done and what is done, not as an example of what should be done. We must be reasonable and not work the willing horse to death.

Increased speed is a great boon to the public always clamoring for rapid transit. By the aid of electricity we have increased the average speed of the cars in Boston from six miles per hour to eight miles per hour and were all the cars equipped electrically this increase alone would make an annual saving to the passengers of 4,152,000 hours or about 474 years. Think of this as one year's saving in one city resulting from the use of electricity as a motive-power for street cars. As a matter of fact the gain in speed will be greater when all the cars are equipped, as the average is now kept down by the horse cars holding back the electric cars running on the same tracks.

The increased speed should not be lost sight of in comparing the cost of operating electric, with the cost of operating horse cars. A comparison on the basis of car days is not a just one. The comparison should be made on the basis of car miles. On the Watervliet road the daily mileage per car has been nearly doubled by the use of electricity.

Another economical feature of the use of electricity is the ability to haul one or even two tow cars. We can double or even treble our carrying capacity in case of emergency; and the extra plant kept for such purposes is in the cheapest form, representing a comparatively small invested capital, and subject to but little deterioration. Compare this with the cost of keeping extra horses sufficient to double or treble our carrying capacity. The difference is enormous.

On those roads or lines where the traffic is great and constant, we will have larger cars. By using the radial truck or double trucks, we can handle thirty-foot cars as easily as our present standard form, and do away with the annoying and destructive teetering inseparable from a long car mounted on a six-foot truck. We can nearly double the seating capacity, and still use but one conductor and one driver.

From the foregoing, it is evident that electricity admits of many economical changes, and that, in many ways, we may hope to reduce expenses by its use, at the same time giving better service. What we must look to, of course, is the ultimate commercial result. Whatever may be said pro and con, the commercial result must be the final criterion. We are now receiving some light in this direction from the annual reports of the roads in those states where the statutes require such reports. Such statistics are of of great value, for whatever difference may exist as to classification and arrangement, the total expenses and the total receipts are bound to appear in some form or other. From the reports of the Railroad Commissioners of New York and Massachusetts for the year 1889, we extract the following :

EXPENSES OF STREET RAILWAYS, NEW YORK STATE, 1889.

Horse Roads.—Average proportion of receipts to operating expenses, thirty-three roads, 79·39 per cent.

Electric Roads.—Average proportion of receipts to operating expenses, two roads, 53·50 per cent.

EXPENSES OF STREET RAILWAYS, MASSACHUSETTS, 1889.

Horse Roads.—Average proportion of receipts to operating expenses, thirty roads, 82·87 per cent.

Electric Roads.—Average proportion of receipts to operating expenses, two roads, 55·50 per cent.

In 1888, the gross earnings and operating expenses of surface and elevated roads in three states were as follows :

RECEIPTS AND EXPENSES PER PASSENGER, 1888.

	Gross Earnings.	Operating Expenses.	Net Earnings.
	<i>cents.</i>	<i>cents.</i>	<i>cents.</i>
Elevated Roads.—New York State,	5'01	2'81	2'20
Surface Roads.—New York State,	4'94	4'02	'92
Third Ward Electric Railway.—Syracuse (1889),	4'92	2'78	2'14
Surface Roads.—Pennsylvania,	5'59	3'18	2'41
Surface Roads.—Massachusetts,	5'10	4'28	'82
Boston and Revere Electric Railway (1889),	4'70	2'71	1'99

The column of operating expenses contains some very significant figures.

Such figures are more convincing than any labored argument. In time, as we have more of these reports, the sceptical will become convinced and the doubting will be satisfied.

DURABILITY.

We may recognize the present economy of electrical power; but, we ask, will the apparatus last? Is it durable? Will it not wear out in one year, two years or three years?

It is difficult satisfactorily to answer such questions. A Van Depoele road was put in operation at Lima, O., July 4, 1887. So far, the apparatus has shown no signs of wearing out. The Eckington and Soldiers' Home Railway, in Washington, was started October 17, 1888. Senators and Representatives still say it is the finest street railway in this country. The Omaha and Council Bluffs Railway was opened to traffic in October, 1888, with ten cars (twenty motors). I am informed that, of these original motors, not a single armature or field has been lost, with the exception of a few struck by lightning before being properly wired for the lightning arresters.

There are certain parts which we expect to wear out; the gears, the shells in the bearings, the trolley wheels, and so forth; but these are provided for. The iron frame of the motor has no wear, and should last indefinitely, unless accidentally broken. The fields and armature are not subjected to wear, and should last indefinitely, unless burned or injured by accident. The electrical part of the apparatus is all right; the wear is mainly on the mechanical parts. It is the mechanical rather than the electrical engineer that we look to now for improvements. When it is generally recognized that we have, to a great extent, eliminated the electrical difficulties and reduced the problem to one of mechanics, the street railway companies will be ready to push forward with full confidence.

RELIABILITY.

That some difficulties are encountered in the operation of electric cars cannot be disputed. Even though these difficulties, these mishaps, these accidents, be slight, if

they interfere materially with the regular operation of the cars, if they cause breaks in the schedule, then they are matters for serious consideration, and perhaps for more serious consideration than the actual cost of repairs involved. The public are exacting in this respect, and will not tolerate delays and unreliable service. It is difficult to secure data in reference to lost trips on roads which are operated independently of the electric companies. On the West End Road, in Boston, during the months of June, July, August and September, of last year, 33,665 round car trips were made, covering a total mileage of 364,754 miles. *Not a single trip was lost.* This is certainly a satisfactory record as to reliability. Similar results have been obtained on many other roads; but the West End is, perhaps, one of the most difficult of all the roads to operate electrically.

On a purely electric road, if a car breaks down from any cause, the next car pushes it home and the delay is slight. I saw one day in Boston a string of horse cars blocked by the cutting of a ditch across the street. Each car, as it came up, had the horses removed and driven around, while the car was pushed across by hand. This entailed much delay, and five cars were soon collected in line. Then an electric car came along, the horses were all removed, and the electric car pushed the five cars across at once. Here was an unexpected example of how time may be saved by electricity.

The success of the electric cars in snow-storms is remarkable. It is really astonishing to see the cars running through twelve inches of snow with no apparent difficulty, frequently pushing or pulling other cars, while four steaming horses are hardly able to pull one car. The contrast is great, and many who were doubtful about the ultimate value of electricity last fall are most enthusiastic advocates now. Such work requires extra power and the station must be able to meet the demand.

During the recent blizzard in St. Paul, one of the criticisms on the electric road was, that the drivers lost their heads and cut down the schedule time of the round trip from forty-five minutes to thirty-five minutes—certainly not a

cause for serious complaint. In St. Louis, in Wichita, in Kansas City, in Scranton, in Syracuse, and elsewhere, the electric cars have this winter demonstrated their decided superiority over horse cars, and have shown their ability to run through ten or twelve inches of snow without requiring the tracks to be cleaned. The electric sweepers in Boston are a pronounced success, and the press, the public and the railway officials are unanimous in their praise. We feel confident now that electric cars can run when horse cars cannot, and that it will require such an unusual storm as stalls the steam roads to block electric cars.

To insure reliability, the entire system should be constructed and installed in a first-class manner; duplicate or reserve steam and generator capacity should be provided; extra motor cars should be held in reserve, the proportion depending upon the nature of the service required; and extra parts should be kept on hand, so that an accident can be repaired in the shortest possible time. We should realize that to a certain extent the motors take the place of horses. A motor may fall sick occasionally, and the services of an electrical doctor should always be available.

FIRST COST.

If electricity does all that is claimed for it, then it is a necessity in street railway work. If the railway President investigates and finds that the claims are well supported, that electricity is safe, is economical, is durable and is reliable, then he seeks to know the cost. A really good article is expensive. Electric motors are good articles.

The cost of equipment for a first-class, double-track road, including iron poles (side suspension), fifty-six pound girder rail, one sixteen-foot closed car and one open tow car to each mile of track, suitable generator and steam plant capacity, etc., would be approximately as follows:

PER MILE OF TRACK.

One mile of track (paved street),	\$10,000
One motor and one open tow car, generator and station equipments, line construction, including poles and steam plant,	10,000
	<hr/>
	\$20,000

A double-track road ten miles long would cost on this basis \$400,000, including twenty motor cars and twenty tow cars.

On a road with very bad grades, greater power might be required. If wooden poles be used, the cost of the line would be very materially reduced.

And now a few words as to the future of electric railways. The success of electrical propulsion has been established beyond question. It is only a matter of time, and that a short time, when it will replace the horses on the majority of our street railways. It is only a matter of time, a somewhat longer time, perhaps, when it will be the propelling power on all our elevated roads, for the elevated roads possess ideal conditions for the application of electricity. It is within the bounds of possibility that our steam roads will be run with electricity; certainly this power offers many advantages for the suburban traffic in the vicinity of the large cities. The possible utilization of hitherto neglected water-powers will be one of the factors in determining the extension of electrical propulsion in this direction. Already we see the beginning. The West End Company, of Boston, are building longer cars with radial and double-swivelled trucks. The New York elevated roads are anxiously seeking a solution to the problem of how to enlarge their carrying capacity without rebuilding or materially altering their superstructures. Longer trains are requisite to meet the increased demands. The limit of the capacity of the present locomotives has been reached. Increased weight in the locomotive means are immense expenditure for strengthening or practically rebuilding the roadway. Cables are not feasible, as the strain on the grip would not permit of long trains and it would be difficult to combine speed and safety with any considerable increase in the number of trains. Cables would not permit of satisfactory switching arrangements at the termini and elsewhere. Electricity offers the best solution. Equip each car with motors. Flexible electrical connections can easily be made from car to car as is now done on surface roads to light the tow cars, and the whole train controlled by the driver on

the front platform of the leading car. Electric, vacuum, or air brakes can be used in the same way. It matters not how many cars we have in a train—one or fifty: Each car adds its own power and all work together. There is no dead weight to pull, as in the case of the locomotive. The passengers themselves furnish the weight for traction. The switching arrangements present no difficulties whatever. The motors can be reversed and run equally well in either direction. The train can be controlled from either end and any increase or decrease in the number of cars will not affect the controlling mechanism.

It is difficult to conceive of a more flexible system. It seems to be the ideal system for the elevated roads and is bound to be adopted in the near future.

ON A NEW METHOD OF MEASURING THE HEAT OF VAPORIZATION OF LIQUEFIED GASES.*

BY E. MATHIAS.

[Translated by Chief Engineer ISHERWOOD, U.S.N.]

The calorific methods¹ ordinarily employed are the methods *with variable temperature*, or at the *fixed* temperature of melting ice; but for the object of my researches a calorimetrical method with *constant temperature*, was necessary, and to give different values to that temperature.

With this view I compensate at each instant by means of a known source of heat the cooling of the water calorimeter due to the vaporization of the liquid. That source is the heat developed by the dissolution of a known weight of concentrated sulphuric acid in the water of the calorimeter. The proposed method is thus a *method of zero*; and it is *susceptible of generalization in other ways*.†

* *Comptes Rendus*, 1888, p. 1146.

† There can evidently be taken as the source of heat the dissolution in water of hydrochloric acid, of azotic acid or of any well-adapted solid; the