STREET AND ELECTRIC RAILWAYS

PART II

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CHAPTER I.

HISTORY AND DEVELOPMENT OF ELECTRIC TRACTION.

The early technical history of street railways in America has little direct connection with the problems of traction as they exist at the present time, for, while there are some technical features which are evolutionary and reveal descent from a long line of methods and principles, the sudden change of motive power from horses and mules to electric motors, with but a brief intervening period of cable development, has brought about an entirely new set of conditions. It follows that while the earlier ante-electric history might be studied for its own sake, it embodies very little of pertinent interest and instruction in the study of the modern street railway systems of the United States.

In connection with the text which follows it is deemed proper to say that a great many authorities have necessarily been consulted, although, from 1877 onward, the facts lie very largely within the personal observation of the writer of this report. Among the books quoted are Wright's American Street Railways, Fairchild's Street Railways, Dawson's Electric Railways and Tramways, Martin and Wetzler's Electric Motor and its Applications, Crosby and Bell's The Electric Railway, Bell's Power Distribution for Electric Railroads, Pratt and Alden's Street Railway Roadbed, Clark's Tramways, Rider's Electric Traction, Gotshall's Electric Railway Economics. In addition to these may be mentioned, for their value in regard to technical data, Herrick's Practical Electric Railway Handbook, Foster's Electrical Engineer's Pocketbook, and Dawson's Electric Traction Pocketbook. These have been supplemented by numerous governmental reports, which bear more or less directly on the subject, such as that of Capt. Eugene Griffin, United States Engineers, United States Senate Miscellaneous Document No. 84, Fiftieth Congress, first session, which is believed to be the first governmental report dealing with the subject in this country. These documents have also been supplemented by citations from the columns of the electrical and technical press, particularly the files of the Street Railway Journal, Annual American Street Railway Investments, issued by that journal, as well as the transactions of the American Street Railways Association and kindred national and state societies.

In the third decade of the last century a lumbering omnibus car, called the "John Mason," of which an early engraving is here presented, was drawn by horses over strap rails laid on stone ties through Fourth avenue, New York city. This constituted the first passenger street railway ever constructed. Some twenty years later the Sixth Avenue Railroad of New York city was built, and its moderate success gave great encouragement to further development. Between 1850 and 1855 half a dozen roads were constructed; 30 in the next five years; over 80 between 1860 and 1870; and at the time of the census of 1890 there were 769 street railways in operation in the leading cities of the country.

The cable system, which the present statistics show to be almost obsolete in this country, was introduced in August, 1873, but enjoyed barely a quarter of a century of useful application. For a time it promised to be the dominating factor in the field wherever the traffic was dense enough to recoup the enormous outlay on construction and the heavy cost of operation, leaving to the horse and the mule, or an occasional dummy steam locomotive, all the other lines where passenger traffic was light.

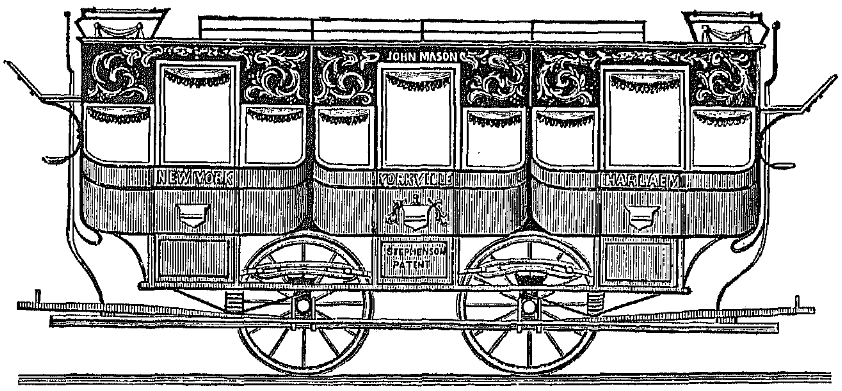
The main ideas of the cable system were suggested at an early date by E. S. Gardiner, of Philadelphia, but the real beginning of this stage of street railway traction dated from the work in San Francisco of Andrew S. Hallidie and his coworkers, Asa E. Hovey, William Eppelsheimer, and Henry Root. It may be noted in passing that the essential principles of the cable system involved a cable traveling in a slotted tube operated by distant driving machinery, and a cable grip, by means of which the car attached itself to the motive cable. Upon this plan and its variations, more than one thousand patents were issued in the United States up to 1890–91, when the superiority of electricity as a motive power had been demonstrated so thoroughly that no new cable system of any kind for any purpose has since been proposed, or is likely to be seriously considered. An immense amount of ingenuity was displayed in the development and perfection of cable systems, and they served the public admirably in many ways, giving facilities never previously enjoyed and suggesting what might be done in the future to afford the dense population of modern cities greater freedom of movement. Moreover, the success of the cable was largely responsible for the welcome which capitalists and engineers gave to the first crude trials of electric traction.

It is an interesting problem to explain why the value of electricity as a motive power was so slowly recognized. The earliest efforts to apply the electric motor to locomotive purposes antedated the beginning of the cable and synchronized with the earliest attempts to utilize steampower, but it was not until fifty years after both of these methods of traction had been put into use that the electric street car or the electric locomotive could be pronounced a definite success. There is but one explanation sufficient to account for the long period of failure and disaster attending the introduction of electric traction—namely, the want of an adequate supply of cheap current with the appropriate methods for its distribution and delivery to the governed vehicle. In some of the earliest attempts the electric vehicle was self contained. In other words, the motor was attached in various ways to the revolving axle and derived its supply of current from primary batteries carried on the vehicle itself. Thus, for example, in the pioneer work done by Thomas Davenport, a blacksmith, of Brandon, Vt., this method was illustrated in his working model. Davenport not only patented electro-magnetic power as a governing principle, but in the autumn of 1835 set up a small, circular railway in Springfield, Mass., over which he drove an electro-magnetic engine.

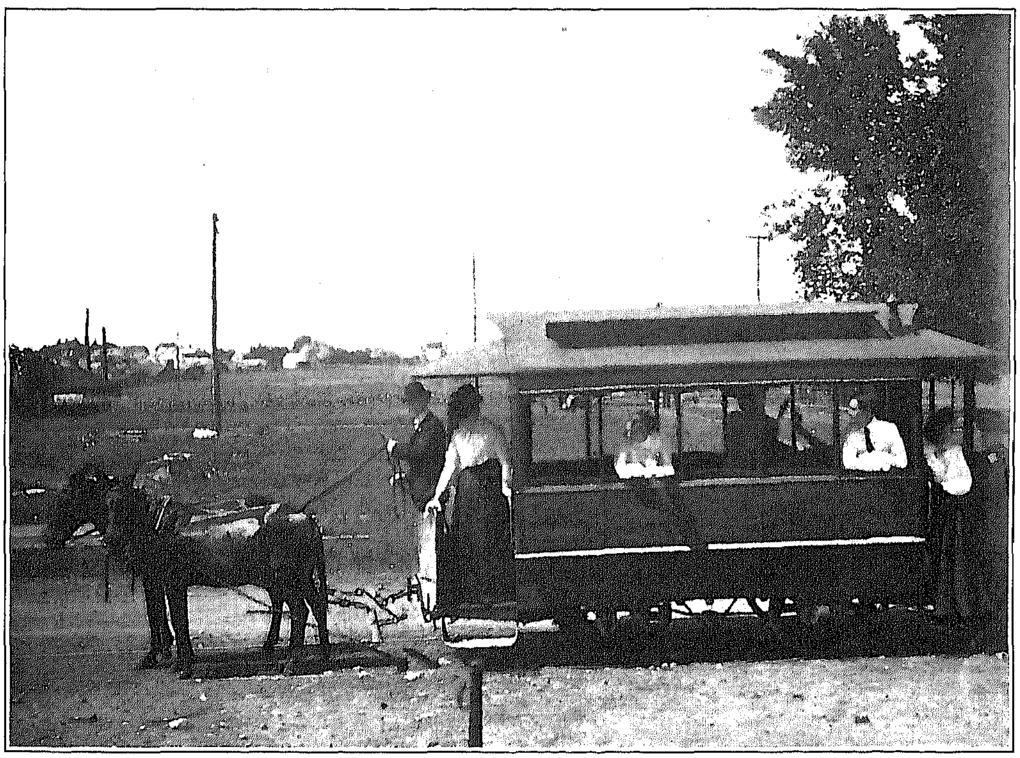
Prof. Moses G. Farmer, a distinguished American inventor and investigator, in 1847 constructed and exhibited in public an electro-magnetic locomotive drawing a little car that carried passengers, back to back, on a track a foot and a half wide. For this he used 48-pint cup cells of Grove nitric acid battery; and the mere statement of this fact will suggest even to the uninitiated the costliness and clumsiness of such methods. In 1850–51 Mr. Thomas Hall, of Boston, exhibited a small working motor on a track 40 feet long, at the Charitable Mechanics Fair in Boston, and while this was a mere toy, and used but a couple of cells of battery, it sufficed to illustrate the principles of a motor or locomotive with a single trail car. About this time (1847) an interesting demonstration was also made with a small working model, of one of the features which has been most instrumental in the success of modern electric methods, that of the utilization of the track as part of the return circuit for the current. Doctor Colton, once a famous dentist in New York city, and noted for his early application of laughing gas in that work, was associated with a Mr. Lilly in the construction and operation of a small model locomotive which ran around a circular track. The rails were insulated from each other, each connecting with one pole of the battery. The current from the battery was taken up by the wheels, whence it passed to the magnets, upon whose alternating attraction and repulsion motion depended; then it returned to the other rail, connected to the other pole of the battery, and thus completed the circuit necessary for the flow of the current. In like manner, in the vast machinery of the electric systems enumerated in this report, the current passes from the power house to circuits of one polarity, through the trolley pole to the motor or electro-magnetic propelling system, thence through the wheels to the track, which completes the circuit by being connected to the other pole or side of the dynamo at the power house. The principles are obviously identical, but it took more than a quarter of a century to develop the proper method of application in all its details.

The most serious and sustained attempt in the early period to operate a self-sustained vehicle or car—which would correspond with the storage battery cars, a few of which are enumerated in this report—was that due to Prof. C. G. Page, of the Smithsonian Institution. About 1850 Professor Page devoted considerable time and attention to the development of electric engines or motors, in which the reciprocating action of a system of magnets and solenoids or armatures was applied by crank shafts to driving a fly wheel, to which rotary motion was thus imparted. This reciprocal motion, as in steam engines, was one of the prevailing features of the early electric motor work in this country and in Europe; but it was not long before its general inapplicability was realized and it was abandoned for the simpler and more direct rotation of the armature before or between the poles of electro-magnets.

On April 29, 1857, with an electric locomotive on which he had installed a large reciprocating motor developing over 16 horsepower, Professor Page made a trial trip along the track of the Washington and Baltimore Railroad, starting from Washington. In order to obtain current for energization, the motor was equipped with 100 cells of Grove nitric acid battery, each having as one element a platinum plate 11 inches square dipped in the acid. Bladensburg, a distance of about 5¼ miles, was reached in thirty-nine minutes, and a maximum speed of 19 miles an hour was attained; the entire trip to and from Bladensburg occupied one hour and fifty-eight minutes. But many disasters happened



THE "JOHN MASON" ORIGINAL STREET CAR.



A "BOBTAIL" CAR STILL IN USE IN 1902 AT DECATUR, ALABAMA.

to the batteries. Some of the cells cracked wide open, and jolts due to inequalities of track threw the batteries out of working order. These experiments must have been extremely costly, and no little discouragement among people in general attended this failure; but Professor Page was not daunted, and for some years continued his work on electric motors, displaying great ingenuity, but not able, apparently, to give up the reciprocating principle.

Another inventor of the early period, whose work should not be overlooked, was Henry Pinkus, who appears to have proposed and provisionally patented, as far back as 1840, the idea of a railway whose motors should pick up their current from the rails. To his work many later inventors were referred by the Patent Office. He, as well as a great many others for several years thereafter, had to endure failure because the dynamo had not as yet been invented. The invention of the dynamo replaced the primary battery as the source of current for the electric railway, and a basis of operation was reached by which the cost would compare favorably with that of vehicles propelled along tracks by the direct application of steam.

The invention of the dynamo was the great and sufficient reason for the upgrowth of the modern industries which depend upon a large consumption of electric current. This fact is brought out by the figures of the census of 1900 in regard to electrical manufactures, where it is shown that of apparatus valued at least at $100,000,000, more than 75 per cent belongs in classes that were unavailable to the public in the days of the primary battery, and that still would be altogether inaccessible if the sources of current supply were little cells with metallic elements dipped in acid solution, yielding current in small volume and at feeble pressure.

Following promptly upon the commercial exploitation of the early magneto-electric and dynamo-electric generators came a sharp renewal of the efforts to perfect the electric railway. These efforts were made on both sides of the Atlantic, the work which attracted the most attention being, perhaps, that of Dr. Werner Siemens at Berlin in 1867 and, about ten years later, of Siemens and Halske. In the meantime efforts were being made in the United States, and in 1879 Mr. Stephen D. Field elaborated plans for an electric railway substantially the same as that soon afterward put in experimental operation by him at Stockbridge, Mass. At this stage of the development of electric railways the problem again arose with regard to the transmission of current from the source of energy to the traveling motor. Instead of using one rail as the receiving part of the circuit to the motor, and the other rail as the return part of the circuit, the idea was conceived of employing a third rail to receive the current, leaving the two outside rails for the return. This third rail was sometimes placed between the two traction rails for contact purposes, sometimes outside them on the same level or raised on short posts, and in some cases, as in mines, was placed above the car or locomotive in the manner of an inverted letter T so that the current could be taken off by some form of traveling contact. The demonstrations with the third-rail method were certainly successful, although the various parts of the apparatus would be regarded at the present time as very crude and cumbersome. It was something, however, that a start had been made and that stimulus had been given to the imaginative powers of American inventors, and it was not long before new electric railway inventions and projects were appearing all over the country.

Some of the work which at this time attracted notice was that of Mr. Thomas A. Edison, who made various interesting experiments in electric railways, which he demonstrated upon a little road built at Menlo Park, N. J. There, during the period from 1880 to 1882, Mr. Edison developed a series of electric railway motors and locomotives which were actually employed in carrying many thousand people and a considerable amount of freight. The records show, that according to a contract made between Mr. Edison and Mr. Henry Villard, in 1881, the former was to build not less than 2½ miles of electric railway at Menlo Park, equipped with three cars and two locomotives, one locomotive for freight and one for passengers, the latter having a capacity of 60 miles an hour. The capacity of the freight engine was to be the hauling of 10 tons net of freight at a cost for power per ton mile less than that of the ordinary steam locomotive. If the experiments were successful Mr. Villard was to pay the actual outlay and to negotiate for the installation of at least 50 miles of electric road in the wheat regions of the northwest. According to Mr. Edison, Mr. Villard paid out nearly $40,000 on account of the work, and there is reason to believe that the work would have gone further had not the Northern Pacific Railroad, with which Mr. Villard's fortunes were then associated, gone into the hands of a receiver. In Mr. Edison's experiments the electric locomotives were built along the usual lines of the steam locomotives, and equipped with cowcatcher, headlight, cab, etc. The motive power was at first applied from the motors to the axle by means of friction pulleys, but this method was found to be unsatisfactory, and in later efforts belts were employed. The armature shafts were belted to a large pulley and countershaft, another belt driving from a small pulley on the countershaft to a larger pulley on the car axle. In operation, the pulleys slipped a great deal before the locomotive actually started, and this led to the introduction of resistance boxes, which were placed upon the locomotive in series with the armature. The locomotive was started with three resistance boxes in circuit, consuming in heat part of the current. After normal speed had been attained, the operator could plug or switch the various boxes out of the circuit, and in this way gradually increase the speed. As a further step, Mr. Edison, finding that the resistance boxes were in the way, had some copper wire wound on one of the legs of the motor field magnet. In this way the resistance was put where it occupied the least room, and where it served also as an additional field coil in starting the motor. Various other developments and improvements were gradually introduced until the cessation of the work in 1882; but throughout the whole period current was fed to the motor through the track, and was supplied to the road by underground feeder cables from the dynamo room of the laboratory. In order to insulate the track from the ground, the rails were insulated from the ties by giving them two coats of japan varnish, baking them in the oven and placing them on pads of tar impregnated muslin laid on the ties. The ends of the rails were electroplated and not japanned, so as to afford good contact surface for the fish plates, and for the copper bonds, which were added to increase the electric continuity of the track circuit.

Early in 1883 the electric railway interests of Messrs. Field and Edison were brought together into the hands of one company. Soon after, at the Chicago Railway Exposition of that year, an electric railway was put in operation by Messrs. Field, C. O. Mailloux, F. B. Rae, and others, which still employed, however, the third-rail method. A circular track nearly a third of a mile in length, 3-foot gauge, ran along the gallery of the building and the locomotive, named "The Judge" after Chief Justice Field, hauled a car along this track. During the month of June, over 26,000 passengers were carried. Similar work was done with "The Judge" at the Louisville Exposition of the following fall. In this locomotive the motor was placed crosswise on the frame so that its armature was parallel with the sills. The armature shaft had connected with it a projecting shaft which transmitted motion by means of bevel gearing to a countershaft carrying two pulleys. These pulleys transmitted power by means of belts to the pulleys on the axles of the drivers. It will be observed that in this experiment, as in Edison's, the motor was placed above the floor of the car and not underneath it. An average speed of 8 miles an hour was made and a maximum speed of 12. The locomotive included original devices for controlling the current depending upon the resistance of a suitable rheostat to be cut in and out of the main circuit. The locomotive was 12 feet long and 5 feet wide and weighed about 3 tons. Current was picked up from the service or feed rail between the two outside rails by means of a traveling "vise," in the jaws of which were inserted bundles of phosphor-bronze wire so arranged, obliquely downward and inward, that whichever way the car moved, forward or backward, a good clean contact would be made on each side of the rail.

Another of the workers in the early eighties was Mr. Leo Daft, an Englishman, who was one of the first to make a commercial business of the construction of motors and of their operation from central power stations for the purpose of driving machinery in such cities as New York and Boston. After some trials of a Daft locomotive on the grounds of his company's works at Greenville, N. J., a line was constructed on the Saratoga and Mount McGregor railroad in November, 1883. This railroad was about 12 miles long with sharp curves and steep grades, and over it the locomotive "Ampere" ran, hauling a regular passenger car. As in many other instances, the motor in this case was placed above the platform of the locomotive. At each end of the armature shaft was keyed a pulley from which belts ran to large pulleys mounted on the countershaft, situated midway between the driving wheels; from the countershaft ran another set of belts to the driving wheels. The reduction of speed from the armature pulleys to the drivers was in the ratio of 8 to 1. On this road also a central rail was used to feed current to the motor, the current being picked up by small phosphor-bronze contact wheels, spring mounted to secure flexibility. During 1884 Mr. Daft built and equipped a small road on one of the long piers at Coney Island, New York's famous seaside resort, which carried 38,000 passengers in one season. In this the system of current supply was also by means of the track. A little later another Daft road was installed at the Mechanics' Institute Fair in Boston, carrying 4,000 or 5,000 passengers weekly for a month. The motor "Volta" used in Boston was then taken to the New Orleans Exposition and operated on a line about one-fifth of a mile in length, between the United States Government building and the main building. This line also carried several thousand passengers.

In 1885 Mr. Daft equipped for the Baltimore Union Passenger Railway Company a line running out through the villages of Hampden, Mt. Vernon, and Woodberry, a distance of about 2 miles, and reaching an elevation of about 150 feet above the city of Baltimore. For this branch two locomotives were built, the motors being placed low down on the floor of the car, and motion from the armature shaft to the car wheels being obtained by internal gears. At each end of the armature shaft a 3-inch phosphor-bronze gear was keyed, and these meshed with large gears 27 inches in diameter fastened to the axle of the driving wheels, the ratio of peripheral speed of armature and drivers being as 3.27 to 1. The track was equipped with a third rail to supply current, placed midway between the outer rails, which served as the return circuit. Part of the system was also equipped with an overhead trolley service. This suburban road continued in operation for some time, until it became part of a general network of electric railways equipped with more modern apparatus.

Mr. Daft, about this time, also equipped several other street railways in different parts of the country employing as a rule two overhead trolley wires, with two trolley contacts, so as to do away not only with the third rail as a means of current supply, but to obviate any use of the track as a part of the circuit. The system of double overhead trolley, which will be referred to later, has continued in vogue in one or two places down to the present time. Throughout this period Mr. Daft was also engaged in a series of experiments on the New York elevated railroads, to which work allusion will be made elsewhere.

One of the men to whom the street railways owe much in their technical development was the late Charles J. Van Depoele, a Belgian, whose father was master mechanic for the East Flanders Railway System. Van Depoele's trade was that of a cabinetmaker, but he devoted all his leisure time to electrical experiments.

In the summer of 1869 young Van Depoele emigrated to this country and began in Detroit the manufacture of art furniture. With the income derived from his growing business he was able to indulge his taste for electricity, and soon made some of the earliest successful arc lights and dynamos for illuminating purposes. His greatest hobby, however, was the propulsion of street cars by electricity, upon which he had been working as far back as 1882. In the winter of 1882–83 Mr. Van Depoele had a short experimental line running in Chicago, and during the same year he operated a car at the Industrial Exposition in that city, taking current by means of an overhead wire. He was encouraged by the results obtained in this way, and in the fall of 1885 made a contract with the directors of the Toronto (Canada) Annual Exhibition to run, single track, a train of three cars and a motor car from the street railway terminus to the exposition, a distance of 1 mile. On this system, which was operated successfully and carried an average of 10,000 passengers per day, a speed of 30 miles an hour was attained. The track was used as the return circuit, and on top of the car was placed one of the first illustrations of the "underrunning" trolley now commonly employed. The contact wheel was carried by a pivoted beam, the latter being provided with a spring on one end pressing the wheel at the other end up against the underside of the overhead wire. A flexible cable connected this contact wheel with the switches, rheostat, and motor on the motor car. The illustrations of this old road show in crude form the modern central overhead wire, underrunning trolley and trolley poles, side bracket poles for suspending the wires, and the insulated track return.

It might be said that this was not a street railway in the strict sense of the term, although it ran through the streets. Mr. Van Depoele's next step was the equipment of a regular street railway at South Bend, Ind., where no fewer than five separate cars were operated at one time, something which had never before been attempted or even supposed possible. This road derived its current from a generating plant driven by waterpower. The equipment of the road consisted of open and closed four-wheeled cars. On each of the closed cars was placed a 5-horsepower motor, while a large open car was equipped with a 10-horsepower motor. The motors were placed under the cars between the wheels, and the axles were connected by means of sprockets and link belt. This innovation had been found to be desirable, as the motor was in the way when above the car platform, and the distance between the armature shaft and the driven axle was too great. Moreover, the motor, when above the platform, occupied space needed for passengers. According to Mr. Van Depoele's own account of this road, a variation was attempted in the trolley contact. The copper trolley wire one-quarter inch in diameter was suspended above the track by means of cross wires fastened to poles placed near the curb. From the underside of this copper wire hung a tiny car fastened to a flexible cable, which passed to the inside of the motor car, and was there fixed in connection with the switches, motor, etc. This car or trolley on the wire traveled with the car on the track and made a perfect contact. This device, and modifications of it, were seen on other Van Depoele roads, but were soon abandoned for the underrunning contact. On some Van Depoele roads, however, a form of overrunning trolley wheel was tried, which traveled along the upper surface of the trolley wire and was held in position by means of a heavy balance weight. In 1885 Mr. Van Depoele contracted with the president of the New Orleans Exposition for a road nearly a mile long, with a carrying capacity of about 200 people, to be operated on the grounds. This was equipped with a motor car and two large open cars. The motor in this case was placed in the center of the floor of the car, the two middle seats being removed for the purpose. This line was equipped with contact wheel, upward-pressure trolleys, the wheel making contact on the underside of the overhead wire, as at Toronto. The experiment at New Orleans, La., was followed by several contracts for roads at Minneapolis, Minn., Detroit, Mich., Appleton, Wis., and Montgomery, Ala. The road at the last-named place was equipped with 12 cars and began operation in 1886.

Considerable discussion arose as to the scope of Van Depoele's work and the importance of his inventions, not a little of which related to the underrunning trolley contact, one of the features which renders the modern systems commercially practicable. It was alleged that Van Depoele had simply carried out or modified ideas and suggestions already in existence. It was asserted, for example, that in systems of electric train signaling, some kind of a trail contact device or trolley had been employed to get current or signals from an overhead conductor to the instrument on the car, and that when it came to the operation of street railways, the difference in method was unimportant.

In reply to this contention it was pointed out that many able inventors, when first confronted by the problem of overhead contact, did not avail themselves of what had been suggested or developed in the electric railway signaling art, but started out on the new and independent line of overrunning trolleys. So far as Mr. Van Depoele's work is concerned, it may be stated here as part of the historical record that the courts sustained his claims, and that in a well-known decision Judge Townsend of the United States circuit court said:

No one can read this record without being impressed by the fact that Van Depoele was more than a skilled mechanic in the art of electrical railway propulsion. The Patent Office has raised a presumption in his favor as an inventor by the grant of numerous patents to him. Some thirty have been introduced by complainant, several of which cover highly meritorious inventions which have largely contributed to the successful practical operation of the trolley roads throughout the country. In fact, the construction covered by his earlier patent for an overhead underrunning trolley shows that he appreciated the problems involved in varying lines and curves, and to a limited extent by said device ingeniously provided for their solution.

The inventors in the art of electrical propulsion, signals, or telegraphs, had failed to provide for an operative contact device at the distance from the car required for the operation of the underrunning trolley road except by unwieldy and impracticable structures on the roof of the car. They had failed to adequately provide for considerable variations from practically straight lines of travel. In their later attempts to do so, they had constructed or adopted contrivances which departed from the earlier devices now claimed to show lack of patentable novelty, and thereby furnished strong proof that the changes made by Van Depoele were not obvious ones. Defendant's expert is forced to admit that the advantages of an underrunning trolley were not obvious and that the earlier constructors must have been in doubt as to the efficiency of such a system, and that the prior underrunning overhead devices would have led a person away from rather than toward an upwardly pressed hinged conductor. In these circumstances the new use of old principles does not fall within the rule of a double use. I have been unable, therefore, to adopt the view of counsel for defendant, that the art of conducting electricity from a conductor to a translating device on a moving vehicle was sufficient to enable the skilled mechanic to construct the device of said first patent. In respect of the underlying fundamental object and result of the paper patents for signaling devices and the Van Depoele device, the transfer was to a branch of industry but remotely allied to the other, and the effect of such transfer has been to supersede other methods of doing the same work.

That no great confidence was entertained in the early eighties as to the feasibility of the overhead contact method of obtaining current for an electric car is to be inferred from the expensive installation made in Cleveland in 1884 by Messrs. Edward M. Bentley and Walter H. Knight, and put in operation by them in August on the tracks of the East Cleveland Horse Railway Company. Two miles of the road were equipped with a little underground conduit placed between the rails and running the entire length of the road. In this conduit was placed the feeding conductor, and the high voltage current for the Brush series wound motor was picked up from it by means of a "plow," which passed through the slot in the conduit, and by sliding contact on the conductor maintained connection with the sources of power. A photograph of the first car equipped to travel over this track is here shown. It was an old horse car equipped with a small arc lighting dynamo driven as a motor. Two other cars, with similar motor equipment, but with variations in gearing were also tried; the last being furnished with spur gearing. The body of the gears was built up of paper, like a paper car wheel, in order to deaden the noise. In the third car, also, the motor was carried by a separate truck, its shaft lying longitudinally of the car, and geared with a parallel countershaft which drove the two axles by bevel gearing. This line, which was in many respects a forerunner of the conduit systems since successfully operated in our largest cities appears to have worked very well, not only in ordinary weather, but through the unusually deep snow of the winter of 1884–85. As a matter of fact this seems to be the first regular electric street car equipment installed in America, operating for fare like the old horse cars.

The same Bentley-Knight system was laid down on Fulton street, New York city, with the contact conduit at one side instead of in the center between the rails, but for some reason this road never went into operation and was afterwards torn up. Another Bentley-Knight line was later constructed in Boston and remained in operation for some time, but was finally superseded by trolley methods, although apparently it can not be said that the relinquishment of the effort was due to any inherent fault of the underground conduit method. The time simply was not ripe for this development, nor had the prejudice against overhead wires in cities yet become so strong as to prevent the overhead network appearing even where an underground system had already shown itself sufficient to the exigencies of the case. The further important developments of the conduit system will be treated later in a discussion of this branch of the art.

At about the same time some work was being done in Kansas City, Mo., by Mr. John C. Henry, a telegraph operator of considerable ingenuity. It appears that a line had been projected to run from Kansas City to the county seat, Independence, some 10 miles away, and Mr. Henry built his little road with the idea of demonstrating the advantages of electric traction to the owners of the proposed Independence line. A number of new features were introduced, the credit for which was claimed by Mr. Henry, and which certainly belonged to the elementary stages of the practical art. Thus the plan was proposed of suspending the working conductor over the track by means of span wires supported at the side of the road, thus leaving the underside of the conductor free for easy access by the traveling contact. As a matter of fact Mr. Henry used double overhead wires, supported both by brackets and by span wire construction, the wire being No. 1 gauge of hard drawn copper. Mr. Henry was of the opinion that the use of the word "trolley," as applied to overhead wire roads, originated on his little Westport line. His first traveling contact was a little 4-wheel carriage which gripped to and ran along the underside of the wire. It was attached to a flexible cable, which completed the circuit to the motor, and the device was trollied or hauled along by the motor car underneath. At first it was called a "troller," but the name was soon changed to "trolley" by the employees and the public. This was long before trolley roads became popularly known as such.

The motor employed by Mr. Henry was a small Van Depoele dynamo or generator, which developed about 5 horsepower. It was mounted in an iron frame with variable speed changing gears, was supported at one end on the car axle, and was engaged with gearing thereon. The front platform was lowered, permitting the commutator end of the motor to project thereon and to be spring supported. This motor was series wound; in other words, the field magnets were in series with the armature. It was regulated by the use of resistance. This road was visited and studied by a great many people, including Mr. Van Depoele and others interested in the development of the art. In the fall of 1885 Mr. Henry secured heavier machinery and moved from the Westport road to some steam railway tracks owned by the Fort Scott and Gulf Railway Company, where he experimented with high speeds, with the hauling of freight cars, and with grades and snow. In the winter of 1885-86 Mr. Henry arranged to equip the East Street Railway in Kansas City, which had a mile of track completed and upon which four motor cars were placed. Each car had a single 25-horsepower motor attached to one of the axles, the motor projecting through the car, its working parts all being in view of the motorman. The motor was connected to the car axle by planetary gear and the armature ran constantly. The car was operated by the aid of two vertical levers—one to connect or disconnect the motor from the car and the other to apply friction wheel brakes. In these motors the fields were so constructed that their resistance could be varied and the motors be regulated without separate resistance boxes, and the road was arranged to operate at a pressure of 500 volts. In 1887 Mr. Henry contracted to build several roads in southern California, all the machinery for which was built in a crude way in Kansas City. The performance was remarkable in view of the remoteness of the inventor from all the facilities necessary for good scientific work.

Coincident with the work being done at Kansas City by Mr. Henry was that attempted even farther west by Prof. Sidney H. Short, then in the physics department of the University of Denver. As early as the month of February, 1885, a company was organized, under the name of the Denver Electric and Cable Railway Company, to build and operate an electric railway in the streets of that city. An experimental track 300 or 400 feet in length was laid in a circle on the university grounds, and a small car called the "Joseph Henry" carried a great many hundreds of people over it. This work attracted attention and led to more ambitious efforts which, however, were not successful. Mr. Short's work was interesting from its demonstration of the fact that some principles, successful in other departments of electricity, could not be applied to the street railway. There are, broadly speaking, two circuit systems of operating electric devices, namely, the series and the parallel or multiple. In the series system, upon which telegraphic instruments have been largely operated and upon which all the early arc lighting development took place, the current passes successively through every motor mechanism on the circuit, these mechanisms being disposed along it like beads on a necklace, and each device receiving sufficient current to energize it. In arc lighting the circuits extend over large territories, with lamps sparsely scattered here and there, and the series principle is well adapted to it, supplying current at high pressure sufficient to overcome the resistance of the long, thin line wire, and giving each lamp the needed electric motive force and quantity of current. But in street railway work where the device, instead of needing a small quantity of current, requires several horsepower, and where the high voltage would be brought into dangerous proximity to the passengers and vehicles, the difficulty of using the series system would seem insurmountable. For this reason ultimately, if not at first, nearly all inventors whose names have been mentioned constructed their systems to operate upon the parallel or multiple plan, under which the incandescent lamp had already been successfully operated. In the parallel plan the current receiving devices, such as lamps or motors, are not strung along in series but are arranged similarly to the rungs of a ladder, each device being on one step of the ladder, so that as current flows from the generator at a moderately low pressure into the system, represented by the two uprights of the ladder, each step receives only the "divided" current that it needs and for which it has been designed. Applying the kindred analogy of two large water pipes from a reservoir with smaller pipes crossing between them, it will be understood at a glance that from the supply of water circulating in the system, each smaller pipe will allow to flow through it only the quantity of water which its capacity permits it to receive, and no more. It will also be readily understood that any working device, such as a tap or paddle, in any one of the smaller pipes, might easily be cut off or cease to operate, without in any wise interfering with any of the other devices of the same kind in any of the other pipes. Not only is an even greater flexibility of current utilization obtained by this method, but all the current in the system can be set flowing at a predetermined low measure, within the limits of safety. On the other hand, in the series system, in spite of all that might be done to the contrary, the failure of one device to operate would be extremely likely to cut off either the entire system or all the line on the other side of it. Moreover, every addition to the length of the system and the number of devices put on it would require an increase in the pressure or potentiality, in order that the required amount of current might be delivered to the device farthest away as well as to the one nearest the point of current supply.

Professor Short, however, in those early days, was of the opinion that the greatest economy in electric railway work, as in arc lighting, could be obtained by the use of a constant series current of small amount, and for several years, with great ingenuity and perseverance, he endeavored to work out a system of this kind. Various forms of conduit were used to hold the conductor for current supply under the cars, and great improvement was made in this respect. In the first form, for example, a sliding bar contact was carried under the car which traveled in the conduit, and as this bar passed through split contacts in the conduit the current was led into the car. But the broad series plan was destined to failure, whether in the conduit or in the overhead trolley form, although some of the later methods of conduit construction were suggested by these experiments; and the road soon went out of existence. Professor Short was not discouraged, however, but continued for some time after to experiment with the series system until, at last, the success of the parallel system induced him to devote his energy entirely to that method of operation as well as to efforts to improve other features of the work, such as motor construction and suspension. Professor Short is entitled to the credit of using motors which were series wound, i. e., had the field coils and armature in series, as in present practice, while he was also early in his recognition of the superiority of spur gearing with double reduction of speed for the motors employed.

It is interesting to study the lives of men who have worked along these same lines and to note how near some men have come to success, finally abandoning their efforts altogether, or having their work remain neglected and unknown for years. A typical instance of this kind is that of Mr. George F. Green, of Kalamazoo, Mich., a jobbing machinist, who, as early as 1856, built some small electric motors and a circular track, upon which he operated a small car by connecting a stationary battery to the rails, so that the current would pass from the rails up through the car to the motor and then into the other rail and back to the battery; but, like everybody else, he soon discovered that primary batteries were not good for such work. Although he did not abandon his electric railway ideas, he does not appear to have put them again into execution until 1875, some twenty years later, when he contrived to interest some one in the construction of an electric railway with a track 200 feet long. This attracted a great deal of attention locally, and was described in the Kalamazoo newspapers. This road depended upon batteries for current. It could carry about 100 pounds of freight or one passenger. The car had a switch or circuit controller, which in one position opened the circuit to stop the car, and in another reversed the circuit, while at the end of the line the switch struck against a stationary finger which reversed it, causing the car to run back again, the reversing lever being operated by hand. Mr. Green stated that it was his intention to use a dynamo instead of the battery to furnish the current, because it was more economical; but for various reasons, such as lack of funds or of urgency, he did not secure it. It was several years before he secured the patent that gave him the desired status. By this time, however (1891), numerous trolley systems had come into operation all over the country, and Mr. Green's patents were superseded. While he would appear to be entitled to considerable credit for his early ingenuity, no trace is discoverable of benefit derived by the art as a whole from any of his suggestions or improvements.

In the same class with Green should perhaps be included Dr. Wellington Adams, of St. Louis, Mo., a man whose name was at one time quite conspicuous in the controversies over the development of the electric railway, and who has at least some claim to the discovery of one or two of the fundamental principles of the art, although litigation did not result in his favor. As early as 1879 Doctor Adams, then connected with the medical college at Denver, Colo., constructed a small model of an electric railway which was used to demonstrate a lecture on electricity delivered at Colorado Springs. From that time on, and during the period of his residence in St. Louis, Doctor Adams was active in the prosecution of his ideas on electric railways, and a lecture of his on the "Evolution of the Electric Railway," in its commercial and scientific aspects, delivered before the Engineers' Club, of St. Louis, as early as 1884, reveals a remarkable grasp of important principles. Discussing the plans which had been tried of mounting an electric motor on a car and connecting it by means of a leather or chain belt, or by a train of cogs, with the car axle, he pointed out that it was desired to dispense as much as possible with intermediate gears and to connect the motor directly with the axle.

Doctor Adams was also an early advocate of the independent car with its motor equipment, seen in the trolley car of to-day as distinguished from the locomotive type, in which one vehicle containing all the motive power hauled a train of unequipped cars or trailers, and he set himself to work to devise a practical method of applying the power on each car. He decided that the armature of the electric motor must run at a high speed and that its power must be transmitted to the wheels of the car by means of a positive gearing. He illustrated his idea by two types. In one type the motor was actually built into each driving wheel, the wheel being formed of two separate electro-magnetic systems, the field and the armature, both capable of revolving. In this way, obviously, all gearing was dispensed with and the driving power was distributed to each wheel and delivered directly at the point of traction. In another type, which was shown in operation and which conforms more nearly to modern practice, Doctor Adams took the field from the structure of the wheel and built it solidly around the axle between the wheels, the armature, as before, being mounted on the axle and inclosed by the field of the motor in such a way that the revolutions of the armature would result directly without any intervening gears in the revolutions of the car axle and wheels. This mechanism was flexibly suspended by springs from the sills of the car, but not otherwise connected with it; and although such a system would naturally constitute a gearless motor, the power in the electric truck shown by Doctor Adams was transmitted through an epicycloidal train of friction gearing at each end of the armature. As all the parts were in line and moved together, the field being rigidly attached to and forming a part of the car axle box, a motor system with little wear and tear or liability to get out of order resulted. Besides this the electric motor suspended from the sill of the car gave protective flexibility against the inequalities of track, sudden breakings, etc.

This early experimental work of Doctor Adams constituted in later years a large share of his claim to recognition, but he also attracted attention by a scheme for a high-speed electric railway, to be constructed between Chicago, Ill., and St. Louis, Mo., for use at the time of the Columbian Exposition in 1893. At that time Doctor Adams advanced several ingenious ideas, and proposed boldly to utilize train speeds and high pressures of current, which are to-day, in 1903, still the subject of investigation. The most notable work along this line is that being done in Germany, where, on the Zossen Military Railroad, near Berlin, the German Government and a syndicate of manufacturers, aided by some of the best technical talent in the Empire, have been experimenting with cars and locomotives, and have actually succeeded in attaining a velocity of over 130 miles an hour, in some cases applying directly to the vehicle and to its motors an alternating current at the unprecedented pressure, for tractive purposes, of 13,500 volts. The difference between this work in Germany, which promises to be fruitful of valuable results, and that of Doctor Adams is that, while apparently large sums of money were raised for the Chicago-St. Louis line, it never materialized so far as the public was concerned, and remains a curious chapter of failure pointing in the right direction.

Without in any way belittling the splendid work done by Van Depoele and the other pioneers whose efforts have been reviewed briefly, it must be admitted that the modern era in street railway work dates as much from the equipment of the street railway system at Richmond, Va., by Frank J. Sprague, as from any other landmark in the history of this industrial development. Mr. Sprague, who was a lieutenant in the United States Navy, from which the electrical ranks have drawn some of their most notable recruits, turned his attention to electricity while quite young, and was one of the fathers of the modern power motor. Encouraged by the cooperation of Mr. Edward H. Johnson, then at the head of the Edison lighting system, Mr. Sprague was able to perfect his motor, and to introduce it in a large way, for those days, upon the low-tension incandescent lighting circuits of the Edison company scattered throughout the country. Mr. Sprague and his associates, however, not satisfied with this field, extensive as it promised to become, soon turned their eyes in the direction of electric street railways, which, in 1887, were quite short and had but a few cars. A contract was signed for the equipment of the Union Passenger Railway at Richmond, upon which no fewer than 40 cars were to be placed, 30 of which were to be in use at the same time. This contract called for as many electric cars as were then in service in this country, and the grades in Richmond were such as were generally believed to be beyond the climbing capacity of any electric vehicle. There were 29 curves on the road, 5 of them less than 30 feet radius, and the track was a 27-pound rail loosely jointed, laid in Virginia clay, and some of the grades reached 12 per cent. The contract called for the complete equipment of this road in ninety days. After considerable experimental work, with troubles and disasters of every description, the road was opened for regular service about February 1, 1888.

Among the general characteristics of the system was a small overhead trolley wire, with which the underrunning trolley made contact reenforced by a main conductor, supplied with current by feeder circuits from the central power house. The track constituted the return circuit, the rails being bonded together and connected with a continuous conductor, which was also connected with ground plates and with the water and gas systems of the city. The working potential of the line was 450 volts and the motors operated on the parallel or multiple arc system. The two motors under each car had single reduction gears—that is, one gear was placed on the axle and the other on the armature shaft, and the motors were flexibly suspended. These motors had also fixed brushes, and were operated by the motorman through rheostatic series parallel controllers, with sectionalized field coils at each end of the car. Very soon the single gears had to be abandoned for double reduction gears, although a reversion to the single reduction gear soon took place. The motor armatures were double ended, having a commutator at each end cross connected, so that but one top brush on each commutator was used. Although most of the motors were built in one of the best electric shops of the country, they were so inadequate for the heavy work demanded of them that every one of them had to have its field magnets and armatures rewound, and its commutators changed.

At that time it was generally believed that an ordinary 16-foot car could easily be operated by a couple of motors of from 7½ to 10 horsepower each, and even one motor was considered equal to a task which had previously been discharged by a team of mules or horses. It did not take very long for the managers of the new electric roads to learn that while motors of 1 or 2 horsepower might be sufficient to keep the car moving, much greater power was needed to start up the car from a state of rest, especially with a heavy load of passengers, and from that time on the capacity of the motors was increased. A great amount of attention was also given to their insulation—a necessary precaution, as the motors were then run entirely open and exposed to dust, mud, and weather. There was also a great deal of trouble with the brushes on the motors, and before carbon blocks were adopted finally for this purpose brushes built of copper and even of solid bars of bronze were tried. The first flat brushes used on the Sprague motors were solid or of laminated copper, which wore through quickly, bent over, and formed an arc around the commutator. Oblique and tilting forms of brushes were also put in use, but the resultant wear upon the commutators was very great, necessitating endless repairs. Moreover, many difficulties developed in connection with the overhead system, and Mr. Sprague states that probably not less than fifty modifications of trolley wheels and poles were used before what is now known as the "universal movement" type was adopted. The same was true of overhead construction at curves, and at the switches or turnouts where the trolley wheels had to leave one line of motion and take up another.

In spite of all the difficulties, the Richmond road continued operation and attracted wide attention in the street railway world and in financial circles. At that time the question of equipping the West End Railroad of Boston, one of the largest systems in the country, with cable, was being considered; one of the arguments for its adoption was that with the cable a large number of cars could be kept in motion at once, which, in the opinion of street railway managers, was not yet possible with electricity. The president of the Boston system, with some of his officers, visited the Richmond road, and was shown no fewer than 22 motormen starting up their cars one after the other as rapidly as headway could be obtained. This experiment was conclusive, and settled the fate of the Boston cable project. But successful results were attained only by ceaseless effort and unremitting experiment. In winter the wires would become so coated with sleet that the trolley wheel could not make contact with the incased wire. This trouble has since been met by sleet cutting devices; but at that time it was nothing unusual to put a man on top of a car with a broom or stick to pound the trolley wire and free it of ice, or even to hold up the trolley wheel in contact, acting as a human trolley pole. Another difficulty was experienced with thunderstorms. At Richmond the long overhead circuit, entirely unprotected by lightning arresters and with numerous ground connections through the motors and lamp circuits, provoked constant discharge. The line was frequently struck, the discharge often passing through the incandescent lamps and shattering the carbon filaments. After a time the engineers learned, as a safety precaution, to turn on the lights during a thunderstorm. During such storms, also, the discharge would sometimes go to ground through the motor fields, burning them out, and sometimes through the controllers. Choke coils to fend off the lightning were soon installed on the cars, and various kinds of lightning arresters were devised, but such discharges long remained a serious impediment to trolley work.

It is, of course, quite beyond the scope and aim of this report to give credit to each inventor for his specific contribution. The intention is simply to give a short continuous record of the stages by which the street railway system has reached its present development. But the separate steps of success and achievement have become associated with the names of certain individuals, and in some instances the decisions of the courts have reenforced or determined the weight of public opinion. This was true in the case of Van Depoele in his perfection of the underrunning trolley, so was it also in the case of Sprague in his contribution to motor suspension. A decision of Chief Justice Shipman in the United States circuit court of appeals in the second circuit is here quoted because it presents succinctly the state of the art and describes Mr. Sprague's service. It is a decision which has been quoted by other judges in litigation on kindred issues. Justice Shipman said:

As soon as the use of an electric motor for the propulsion of cars upon a street railway was thought to be attainable divers methods were invented which were intended to enable the motor to act efficiently, economically, and certainly upon the car axle. At first the motor was supported by or on the car body and afterwards it was upheld upon a separate platform. The state of the art upon the subject is so fully stated by Judge Sanborn in Adams Electric Railway Company *vs.* Lindell Railway Company (77 Fed. Rep., 432, 40 U. S. App., 482) that it need not be restated here. Sprague hung the motor under the car body directly upon the axle of one of the pairs of wheels by an extension or solid bearing attached directly to the motor. He used a magnet having a yoke and pole pieces, and by sleeving one end upon the axle he caused the armature, which was carried between the poles of the magnet, to be held with firmness and the armature shaft to be held in alignment with the car axle. The opposite end of the motor was upheld by springs extending to a crossbar on the truck frame. He also relieved the weight upon the axle by a spring support from the truck of the vehicle. The motor was thus hung below the car, one end being centered upon the axle and the other end being flexibly attached by springs to the truck frame. The effect of the mode of construction is explained in the specification as follows: "The armature being carried rigidly by the field magnet, these two parts must always maintain precisely the same relative position under every vertical or lateral movement of the wheels or of the car body; and as the field magnet which carries the armature is itself centered by the axle of the wheels to which the armature shaft is geared, the engaging gears also must always maintain precisely the same relative position. At the same time the connection of the entire motor with the truck is through springs, so that its position is not affected by the movements of the truck on its springs." The simplicity and comparative lightness of the general plan upon which this motor was constructed and the adaptability of the means to the required result made the motor successful, and other preexisting methods of construction disappeared to a great extent.

Any history of modern street car development must include the development of elevated railways, which, occupying main lines of thoroughfare, with tracks elevated above the street surface, so as not to interfere with ordinary vehicular traffic, transport a large number of those who travel daily from one part of an urban center to another. Such roads have been peculiarly, though not exclusively, an American development and are restricted in this country to a few of the largest cities, such as New York, Brooklyn, Chicago, Boston, and Kansas City, in most of which they have already become an integral part of the surface street car systems, operating under the same management and providing for exchange of traffic. This subject will be dealt with in another part of the report, but it is proper here to note that some of the earliest work of such men as Daft, Sprague, and Field in the application of electric motors to short haul passenger transportation was done on the elevated roads of New York, where many important lessons were learned. The use of steam on the elevated roads continued for many years without complaint, and the service rendered to the various communities was remarkable for its efficiency, safety, and regularity. But whether from the increased amount of travel, necessitating more frequent trains, or from the inconvenience and discomfort due to dust, ashes, escaping steam and gas, dropping oil, and the like, or from the inability of steam locomotives of the necessary medium size to haul heavier trains at higher speeds over the structures, the fact remains that by 1885 a plan had been formed for equipping sections of the Ninth Avenue and the Second Avenue Elevated railroads in New York city with electricity.

Mr. Daft equipped the Ninth Avenue line from Fourteenth street up to Fifty-third street, a distance of 2 miles including a heavy grade. A third rail was laid between the two traction rails as a conductor to deliver current to the motors, and the outer rails were made the "return." The electric locomotive built to haul the train of cars had driving wheels 48 inches in diameter, and was equipped with a motor of 75 horsepower, having a normal speed of 18 miles per hour and a maximum of 40 miles. The complete motor weighed 9 tons, and was 14 feet 6 inches in length, with a normal width across the standard gauge track of 4 feet 8½ inches. This motor was supported at the rear on a shaft resting in bearings. Its front end was supported by a long screw which passed through a threaded eye. This screw was turned by a hand wheel. The armature shaft carried a friction wheel 9 inches in diameter, bearing upon a larger friction wheel 3 feet in diameter, geared to the axle of the main driving wheels. Thus, by turning the large screw, the upper friction wheel could be pressed against the lower to any desired degree, and in this manner power was transmitted by friction from the armature to the drivers, the amount of friction being regulated at will according to the load. Mr. Daft thus obviated the necessity of belts and pulleys, sprockets, link belts, etc. By means of the screw, also, the motors could be raised to clear the driving wheels, so that the armature could be taken out and inspected or repaired with convenience. This locomotive was provided with electric brakes, consisting of large electro-magnets, which, being energized by current from the track, were attracted by the wheels, and pressed against them like an ordinary brake. The terminals of the compound winding of the motors were brought to a regulator or controller, convenient to the hand of the motorman in front of the locomotive, and by the motion of a lever across the terminals, the resistance of the field magnets could be altered, producing corresponding changes of speed. The current was picked up from the central third rail by a bronze contact wheel 15 inches in diameter. The motor proved too light for its work, and was afterwards reconstructed. But neither then nor now does it appear that the locomotive principle was found best adapted to street electric traction, however well it may have been adapted to steam traction.

Meantime, Mr. Stephen D. Field, as representative of the Edison-Field interests, began work on the Thirty-fourth street spur track of the Second Avenue Elevated road, introducing an electric locomotive which, outwardly at least, resembled nearly all of the electric locomotives which have later come into actual service. But in the Field locomotive the motor was mounted upon the rear truck, and was connected to the driving wheels in a manner exactly like that employed in the ordinary steam locomotive. In other words, the motor shaft was directly connected with the drivers by means of a crank and side bar. Another of the features of this machine, which was series wound, was that it was regulated by means of a liquid rheostat or resistance placed in the cab. This rheostat consisted of a trough divided into two compartments filled with acidulated water. A metal plate on either side of these troughs acted as a terminal for the feeding circuit which was led in by two copper cables. The speed of the motors was regulated by the insertion or withdrawal from the troughs of two slabs of slate suspended over the troughs and operated by a long lever, thus varying the resistance from almost nothing up to any desired degree. Mr. Field had other ingenious devices for reversing, for shifting the brushes to prevent sparking at the commutator, etc. This locomotive had a total weight of over 13 tons, and hauled a passenger car which was regularly hauled by a 13-ton steam locomotive. It also handled easily one of the regular large elevated coaches up grade at 8 miles an hour, and was often operated under a potentiality as high as 1,100 volts.

In contrast to Daft and Field, Sprague advocated the abolition of the locomotive and the installation of one or more motors under each car. His arguments appear to have been final and conclusive. The locomotives have disappeared and motor cars have taken their place. Mr. Sprague made his experiments on the Thirty-fourth street branch of the Third Avenue Elevated, placing two motors on the car trucks. The motors being thus grouped in parallel on a constant potential circuit, and driving from opposite ends of the motor shaft, a very intense rotary effort or torque was secured in starting, by having an intense magnetic field and raising the armature potentiality gradually. A system of braking was tried which consisted in converting the energy of the train into current, delivered back to the line from the motor, which thus temporarily became a dynamo without reversal of contacts. The current was taken up from a central rail by three contact conductors, two of which were bronze wheels working on pivoted arms under compression springs. Special switches were provided for handling the motors, breaking the main circuit, reversing the armature circuit, cutting the armature partially from the line, and closing it upon a local regulating apparatus. A potentiality of about 550 volts was used, current being obtained from 5 Edison incandescent lighting dynamos placed in series, the circuit being led on Western Union telegraph poles to the track from a power plant almost a mile away. A number of other interesting features were included in these experiments, but evidently the time was not ripe for the change in New York. It was not until fifteen years later that electricity was finally adopted as the motive power of the New York elevated system, although meanwhile it had been adopted with success on the elevated systems of Chicago, Brooklyn, and Boston. The demonstration made at the World's Fair in Chicago in 1893 was sufficient warrant for resorting to electricity on those roads. An elevated structure known as the Intramural Railway made an almost complete circuit of the grounds, being nearly 3 miles in length, comprising 14,800 feet of double track and 1,900 feet of single track. Over this road were run 15 trains, each consisting of 3 open trail cars and a motor car. Each car was mounted on double trucks and was 50 feet in length. The trailers when loaded weighed 22 tons and the motor car 30 tons. Each motor car was equipped with 4 motors—one on each axle. The motors were single reduction, so geared as to work at a maximum speed of 35 miles an hour, and were capable of an output of about 135 horsepower, thus giving each motor car something over 500 horsepower. The current was picked up from the track by means of a third rail placed outside the traction rails, with a sliding contact on the motor car. Current was furnished from a special power plant, with a generator of 2,000 horsepower, a capacity theretofore unknown in connection with street railway operation. This road remained in operation throughout the fair, and is reported to have carried with success and safety no fewer than 125,000 persons in a single day. After this no question remained as to the practicability of operating extensive elevated lines with electricity.

The record of experiments would not be complete without a reference to storage batteries, which at first gave great promise, but which, from various causes, have since been almost entirely abandoned. All of the earlier experimental work with electric traction depended upon primary batteries as a source of current. The vehicle in some of the larger types, as, for example, that of Professor Page, at Washington, carried its own battery and was thus self-contained. There are so many obvious advantages in a self-contained vehicle that no wonder need be entertained at the persistence with which these earlier attempts were renewed, when the storage battery came to the aid of experimenters. A battery car does not require a cumbrous system of overhead wires more or less disfiguring to the street, nor does it require a third rail, or a complicated system of conduit construction as in the case of cars with underground contacts reached through a slot in the track. Neither do such cars require an elaborate system of mains and feeders for bringing the current to the track from the power house, nor for effecting the return circuit. Moreover, in case the power house is for any reason temporarily thrown out of service, each car with its storage battery is equipped with enough current to maintain its schedule, whereas with trolley or conduit cars all the cars out on the road are instantly stopped the moment the current is cut off, and are compelled to stand still until the current can be thrown on again.

These and other considerations led to interesting experimental work as early as 1880 and 1883, both abroad and in this country. Storage battery cars were put in service in New York city, Philadelphia, Washington, and elsewhere. The most ambitious work of this character was done in New York city in 1887 and 1888 with the system of Mr. E. Julien, of Belgium, as a result of which 10 or 12 cars were in operation for a considerable time on the Fourth Avenue road. The ideas of Mr. Julien were considerably modified by Mr. C. O. Mailloux and excellent results were obtained, while other encouraging experiments were made in Philadelphia under the direction of Mr. Anthony Reckenzaun, of Vienna. Simple as the storage battery idea is in conception, it proved to have a great many difficulties in its application. Some of these arose in connection with the early types of storage batteries, which were found quite inadequate to withstand the strain of street railway work. Batteries broke down very rapidly under the heavy discharge of current necessary at intervals and proved liable to short circuit from jolts and concussion on the tracks. The weight of the batteries also proved a considerable drawback, the cells first used weighing not less than 100 to 125 pounds per horsepower hour of energy stored, which limited the radius of the car very seriously. Lighter cells giving an output of 1 horsepower per hour with 50 to 75 pounds of battery were found to be too fragile for such work. Another difficulty which proved insurmountable was the annoyance to passengers from sulphuric acid gas escaping from the cells. Moreover, the acid scattered by the jolting of the car corroded and weakened its structural material. Another difficulty arose in the handling of the relays of batteries at the power plant, and various ingenious devices and contrivances were employed by which the exhausted batteries, when they came in, could be quickly exchanged for batteries freshly charged. To obviate the necessity of any such mechanism the batteries were sometimes left on the cars all the time, but this, of course, necessitated the doubling of the rolling stock. For several years experiments with the storage battery continued with varying success. But although a few such cars were in operation as late as 1902, as shown by the statistics, the last of those in New York city were withdrawn from the streets in 1903 while this report was in press.

CHAPTER II.

ROADBED, TRACK, AND ELECTRIC CONSTRUCTION.

I.

ROADBED AND TRACK.

With regard to the statistics of track and roadbed it may be pointed out that at the census of 1890 the railways that used motive power other than steam were confined almost exclusively to urban districts, and were properly classed as "street railways," but since then the application of electricity has enabled these roads to extend their lines greatly in rural districts, and a considerable proportion of the trackage is now outside the limits of cities, towns, or villages. That the use of electric power has been the principal factor in the development of these railways during the past twelve years is shown by Table 4, page 8, which presents for the years 1902 and 1890, the number of miles of single track in the United States, classified according to the motive power used.

The increase in the length of track is confined entirely to the railways operated by electricity. The mileage operated by this power increased from 1,261.97 miles in 1890 to 21,901.53 miles in 1902, while a decided decrease is shown in the trackage for each of the other classes of power. Single track roads are characteristic of rural districts, and the fact that the percentage of increase in length of line is greater than in length of track is due principally to the great development of interurban single track lines since 1890. In some cities, as, for instance, in Philadelphia, owing to the narrowness of the streets, the railways are sometimes single track, going out on one thoroughfare and returning on an adjacent one.

Track statistics.—The 22,589.47 miles of track reported for 1902 consisted of 16,651.58 miles of first main track, 5,030.36 miles of second main track, and 907.53 miles of sidings and turn-outs. The further segregation of this trackage according to power used, ownership, and location for the United States and for each state and company is shown in Table 94. Table 86 presents the totals for the United States, and shows the mileage of each of the different classes of track and the percentage which each class is of the total.

TABLE 86.—*Single track mileage and percentage each class is of total: 1902.*

CLASS OF TRACK.	Single track mileage.	Percentage of total.
Total	[1] 22,589.47	100.0
First main track	16,651.58	73.7
Second main track	5,030.36	22.3
Sidings and turn-outs	907.53	4.0
Overhead trolley	[1] 21,302.57	94.3
Other electric power	611.44	2.7
Compressed air	6.06	(2)
Animal	259.10	1.1
Cable	240.69	1.1
Steam	169.61	0.8
Trackage owned	19,038.33	84.3
Trackage leased	3,551.14	15.7
Operated under trackage rights	560.92	2.5
Constructed and opened for operation during the year	1,549.73	6.9
On private right of way owned by company	3,424.96	15.2
On private right of way not owned by company	877.11	1.7
Located within city limits	[3] 13,208.24	65.8
Located outside city limits	[3] 6,855.58	34.2
Equipped with cast welded joints	1,642.68	7.3

[1] Includes 12.48 miles of track duplicated in reports of different companies.
[2] Less than one-tenth of 1 per cent.
[3] Exclusive of the mileage of Massachusetts.

Of the total mileage, 21,914.01 miles, or 97 per cent, were operated by electric power, and 416.36 miles, or 1.9 per cent, by other mechanical traction, while only 259.10 miles, or 1.1 per cent, were operated by animal power, as compared with 69.7 per cent in 1890. Even this heavy preponderance of electric traction has been increased during the preparation of the present report.

Of the total trackage in use by all companies, 84.3 per cent was owned by the operating companies and 15.7 per cent was operated under lease. The mileage of track constructed and opened for operation during the year covered by this report was 1,549.73 miles, or 6.9 per cent of the total; but this does not cover all of the track under construction. A number of miles of electric track were in various stages of completion, but it was impracticable to fix upon any stage of the work at which the trackage could be enumerated other than that of actual completion.

The statistics concerning track located on private right of way refer particularly to rural electric railways. Many of these, after the manner of steam railways, have bought or have had surrendered to them a separate roadbed, either adjoining or independent of the highway. It appears from the reports that 3,424.96 miles of single track were on private right of way owned by the company. Occasionally the railway is built on a private right of way not owned by the company, an example of which would be a toll bridge owned by a bridge company, to whom payment for the privilege of using it was made. There were 377.11 miles of track on right of way of this character. Many of the new interurban electric roads run right across the country, making little use of highways, to which street railways have previously clung so tenaciously.

The inquiries concerning the location of track—whether within or without city limits, were made with the intention of ascertaining the relative length of track operated in urban and rural districts, respectively. In a number of cases it was impossible to determine exactly the trackage that should be assigned to these two subdivisions. In some instances the track was within, or passed through, thickly settled communities that were not organized as cities or towns, and therefore had no corporate limits, and it was difficult to obtain the length that should be considered as within the urban district. In the New England states densely populated communities are often legally part of the town government, which also includes rural districts. Many companies in Massachusetts reported that it was impracticable to make the distinction, and accordingly the trackage for that state has not been included in this classification. For the United States, exclusive of Massachusetts, 13,208.24 miles of trackage, or 65.8 per cent of the total, were reported as within urban limits and 6,855.58 miles, or 34.2 per cent, as outside of such limits.

The increase in the trackage is due not only to the building of new lines, but largely to the extension of the lines of established companies. This is illustrated by Table 80, in which the operating companies reporting in 1902 and 1890 are grouped according to length of line operated.

The average length of line per operating company for all companies was 20.38 miles in 1902, as compared with 7.41 miles in 1890. Thus the average operating company in 1902 controlled almost three times the length of line that was controlled by the average company in 1890. In 1890, of the companies reporting, only 8 operated more than 50 miles of line, while in 1902 the number of such companies had increased to 69. Of the total number of companies reported for 1890, 94.9 per cent operated less than 20 miles of line each, and their combined length of line amounted to 71.5 per cent of the total in the United States; in 1902 corresponding percentages were 75 and 30.7, respectively. Thus, while there are still a large number of companies that operate less than 20 miles of line, the proportion of the total length of line operated by them is not half so great as in 1890.

Roadbed construction.—It is needless to say that one of the most important features of a street railway is its track, and this importance may be brought out more emphatically by regarding the matter from different points of view. A good track is necessary to the smooth and economical operation of cars; it is of importance as bearing on the comfort of the passengers, and the track in its relation to the roadbed and to the thoroughfare through which it runs must be considered from its effect on the convenience of foot passengers and the durability of vehicles using the road.

Of the roadbed it may suffice to say that it is good practice to have a good ballast—for instance, clean, broken stone and sharp, clean gravel or furnace slag—at least a foot deep under the ties, with the space between the ties filled up evenly to the top, with proper provision for drainage connection with the sewers. In exposed track coarse, large stones placed edgewise at the bottom of the ballast are common, in order to provide for draining or sewerage; filling in the interspaces with the gravel or other ballast, thoroughly rolled or tamped down; and upon this bed are placed the ties which carry the rails. It has sometimes been the practice to set the rails or track construction upon a bed of concrete, or upon long concrete beams or stringers under the rails. In Buffalo the concrete bed has been laid entirely across the track, while in Kansas City, St. Louis, Philadelphia, and other cities the stringer construction is used.

The difficulty which has to be considered in connection with the use of concrete for this purpose has been that of track renewal, since, where the rail lies in concrete or where there are steel ties or cross girders thus embedded, the entire concrete portion must be renewed when the rails wear out and new rails are substituted. Some of the most extensive construction within the last few years in Chicago and New York city has been with wooden ties on a broken stone ballast. Thus it might almost be said that as a general thing recent work has developed the somewhat anomalous condition of using the more substantial concrete construction on the smaller roads where traffic is not heavy, and the lighter, more elastic wooden construction on roads with dense and ponderous traffic.

In this connection it may be interesting to note the practice of the Rochester Railway Company, Rochester, N. Y., as reported by the chief engineer, Mr. Le Grand Brown. In addition to track constructed by the ordinary method this company laid considerable concrete beam and steel tie construction. For ties the company used old 4½-inch girder rails cut into 1½-foot lengths, which were inverted and fastened with bolts and clips to the main rail. These steel ties were bedded in concrete, and under the rails were placed concrete beams 12 inches in depth and 14 inches in width. Where the ties were located, a trench 4½ inches below the tie and about 12 inches in width was filled with concrete. The remainder of the pavement between and beside the rails was a 6-inch concrete base, while under the whole was a 4-inch layer of stone chips. Drain tile was laid parallel with the track and connected with the sewers. The pavement was laid upon a cushion of sand 1 inch in depth; and where the street pavement was of brick or asphalt, the concrete was carried slightly above the base of the rail. From 1897 onward this construction was carried out with 6, 7, and 9 inch rails in asphalt, brick, and Medina stone pavements. The track was raised and blocked to grade and line before concreting, little trouble being experienced in keeping it in place during the work, and care was taken to have the concrete well tamped under the base of the rails and around the ties.

With regard to the rail itself there is considerable difference in the practice of street railway companies, to which allusion will be made later. So far as known the first street rail laid was that on Fourth avenue in New York city. This was of the flat type, being nothing more than a single bar of iron with a groove formed in the upper surface, into which fitted the flange of the revolving wheel. This type of rail, with a weight ranging from 30 to 80 pounds per yard, although modified in many respects, was adhered to for a long time. Such a rail was more particularly adapted to light traffic, but even then was found to need vertical stiffening and longitudinal support. In America a small lip or flange was added to the underside to prevent the rail from slipping off the stringer, while in England a second flange was added, and the web was increased in depth. This feature reached such a development in some cases that the rails had a total depth of 2⅝ inches; the longitudinal stringers were abandoned, the rail being supported on cast iron chairs placed at intervals of 3 feet. As most of these rails, however, were used with wooden stringers, fastenings were used, consisting usually of spikes, staples, or lag screws passing through the rails. The rails were joined at the ends by rail joints, which were at first plain flat bars of iron, 3 or 4 inches wide and 8 or 10 inches long, let into the stringers and giving but a weak support to the loose rail ends. The next step from this flat or tram rail was to the T or Vignole rail, identical in most respects with the rail now used exclusively on the steam railways of the United States.

As will be noted from the returns in this report, the T rail has found extensive use among the street and interurban railways, though it is obvious that the conditions on street railways differ materially from those on steam railways. The main considerations which have led to its adoption or use, as compared with the girder rails, are that it is without the tram and groove of girder rails; it does not invite street traffic; it is generally easier to lay; it is cheaper, the price per ton being less than for the girder rails; and, finally, owing to its symmetrical section, a lighter rail can be used under similar conditions than would be the case if the girder type was resorted to. These remarks apply more particularly to roads in cities and their suburbs, since on the interurban railroads, which will be discussed separately, the T rail, with an average weight of 70 pounds, is almost universally used.

Track construction on selected railways.—Perhaps the best way to summarize present methods of track construction in standard American practice, as embodied in this report, will be to consider the practice prevailing in some of the leading cities and street railway systems of the country.

The United Railways and Electric Company of Baltimore uses for construction in paved streets 9-inch grooved rails, laid on Georgia pine ties, 6 inches by 8 inches by 8 feet, spaced 2 feet between centers, the ties being tamped up with 3 inches of gravel and no other ballast or concrete being used. The standard distance between track centers is 10 feet, although this is reduced when necessary in narrow streets. The rails are in 60-foot lengths, and are laid with broken or alternating joints. No tie plates are used, but tie rods are placed every 6 feet. Angle bar joints have been used recently, which on girder and grooved rails are 22 inches long, with 8 bolts, and all are between ties. The company also has some exposed 60-pound T rail, spiked to hewn chestnut ties 6 inches thick, with a face of from 6 to 12 inches, 8 feet long, placed 2 feet between centers. The ballast, 4 inches deep, is filled in between the ties to the base of the rail, sloping off to the roadbed 18 inches outside of the ends of the ties. The rails are 30 feet long and are laid with broken joints, and no tie plates. The standard bond to secure electrical continuity between the abutting sections of rail is a tinned No. 0 copper bond wire, fastened to the rail with channel pins, though some of the heavy bonding is done with No. 0000 wire, while the standard bonding on exposed T rail on suburban lines is No. 0 tinned copper wire, fastened with channel pins.

The rail used in paved streets by the Boston Elevated Railway Company is in the nature of a compromise between a girder and a grooved rail. It has a groove with a lip one-half inch lower than the head of the rail, and is of a form which will not retain dirt, but offers considerable inducement to vehicles. For track construction where the entire street is laid on a concrete base, the ties, which are 6 inches by 8 inches by 6½ feet, are bedded for their entire length in concrete, which is carried down to the bottom of the ties and thoroughly tamped under the base of the rail. Where the pavement is not laid on concrete, the ties are bedded and tamped in gravel, which is brought up to the top of the ties, granite blocks being used for paving between the rails. On reservations, and where tracks are filled in with loam within 8 inches of the top of the rail, the ties are placed 2 feet 6 inches between centers.

Tie plates are omitted where the paving is brick or asphalt on a concrete base; but where the paving is granite, a cast iron tie plate about 1½ inches in thickness is used, so that the height to the top of the rail is about 10 inches. The track construction is securely bonded to the rest of the street by the fact that the tie is bedded in the concrete. The joints are angle bar, with 12 bolts. The form of construction used in outlying streets, where a reservation has been made alongside the roadway so that there is no paving, is to lay a 7-inch T rail mounted on a 1-inch tie plate. The object of so deep a T rail is to secure 8 inches of loam over the ties for raising grass. Most of the recent bonding has been with protected rail bonds.

In Buffalo the company lays a 94-pound girder rail in paved streets, with a rather narrow groove, whose lip is five-eighths of an inch below the head of the rail. Two forms of track construction are employed, both of which depend mainly on concrete to support the rails. Where granite block paving is permitted for the full width of double track, the track is supported on a solid bed of concrete extending about 8 inches below the base of the rail, and is held to gauge and partially supported by the ties placed every 5 feet. Every alternate tie is of metal, the others being of wood. In places where asphalt paving is laid in the "devil strip" the concrete beam form of construction is employed. A wedge-shaped beam of concrete, 18 inches wide at the top and 8 inches deep, is laid under each rail, ties are placed every 5 feet, and concrete is tamped under every other tie at the time the concrete stringers are laid. The remaining ties support the track during construction while the concrete is being laid, and are laid on tamped stone, the paving between the rails being supported in this case simply on a sand foundation, except where it is above the ties. For suburban or outlying streets a 9-inch girder rail has been extensively employed for paved streets, but in macadam and dirt roads a 6-inch T rail, weighing 72 pounds per yard, is used, and if the track is exposed A. S. C. E. standard T rail is laid. The spacing of ties, which are white oak 6 inches by 9 inches by 8 feet, on suburban work is 2 feet between centers, and they are laid on broken stone ballast 8 inches deep. There are no tie plates, but rail braces are used on the outside of each rail and on curves.

Bonding is unnecessary on the electrically welded track used in Buffalo, which has over 100 miles of such track, as the conductivity of the joint is high and the percentage of breakages is low. On suburban work, rail bonds of the protected type applied with a screw compressor are used. As the introduction of a successful electrically welded track practically assures to a rail a length of life limited only by the wear of the head, some calculations have been made at Buffalo as to the probable wear of rails. On some track which ordinarily has cars on two-minute headway but which, during the Pan-American Exposition had cars on a thirty-second headway, the wear was found to be one-eighth inch in four years. The welding process, as carried on at Buffalo, begun in 1899, was notable as being the first application on a large scale of a successful method of welding rail joints electrically. The joint plates are welded to the web of the rail by means of bosses on the plates, which limit the area of the welding to the area of the bosses, and so insure a high temperature at the point of welding, one boss being directly at the joint between the rails, another at each end of the joint plate. The center bosses are welded first and those at the ends afterward. In the welding five work cars are employed. One of these is the welding car proper, which carries the welding clamps and the welding transformers. The second car carries a rotary converter, which receives direct current from the trolley wires and supplies alternating current to the welding transformer. The third car has a motor driven booster for raising the trolley voltage whenever the drop is so great that there is danger that the weld may not be successful. The fourth is a sand blast car, which cleans the rails before welding. The fifth carries a motor with emery wheels for grinding off any inequalities in the joint after it is completed. The number of breakages in the electrically welded track in Buffalo has been a very small fraction of 1 per cent.

The Chicago City Railway Company on the last track that it laid employed a 9-inch girder rail weighing 95 pounds to the yard, with wide tread for vehicle wheels, laid on white oak ties 6 inches by 6 inches by 8 feet, resting on sand, the track being held to gauge by malleable cast-iron tie plates with braces. No tie-rods were used, and the joints were cast welded. As to bonding, a good cast welded joint was used, and a copper supplementary wire was also run, as required by a city ordinance. It has been approximately estimated that a piece of girder rail track of this company was worn out after the passage of 3,000,000 cars; that is, the head was so worn that the car wheel flanges touched the tread of the rail. The wheel flanges used on this road are unusually shallow, being but five-eighths of an inch.

The rail now used by the Cleveland Electric Railway Company is similar to that used in Boston, except in streets like the boulevards, where the tracks run along grass plats. The track is laid on ties that are placed 2 feet between centers except that three are placed under each joint, these being staggered. Three inches of concrete is placed under the ties. Two kinds of joints have been used—the cast welded and the twelve bolt 36-inch angle bar. On a boulevard line recently constructed 80-pound A. S. C. E. standard rails in 30-foot lengths were used, the bonds used being single or double No. 0000 protected leaf bonds, 10 or 12 inches long, placed under the fish plates. Some 90-pound girder rails which have cast welded joints have been used nine years under a three-minute service.

The Denver City Tramway Company was one of the first to employ successfully the T rail in paved streets where the traffic is heavy, and was the first to use what is commonly known as the Shanghai or high T rail. Its standard rail for "downtown" service is a 72-pound 6-inch rail, in 60 or 62 foot lengths, laid on Texas heart pine ties, 6 inches by 8 inches by 6 feet, 21 inches from center to center, in gravel ballast, which surrounds the ties and extends 8 inches below them, except in paved streets, where concrete is used between the ties. During the last four or five years the plan has been adopted of treating all rails with one or more coats of asphaltic paint, which has retarded corrosion and electrolysis, as the local soil is impregnated with alkali and mineral salts. For outlying unpaved streets, standard A. S. C. E. 65-pound T rail, in 60-foot lengths, is used. The rails are butted tightly together, and are always laid in cool weather, since they last longer when little longitudinal expansion is allowed. As to the life of ties, it is reported that in Denver, good Texas heart pine ties last from seven to twelve years; white oak ties have been in use for fifteen years and are still good; red and black oak ties are good for from six to eight years; and native pine and spruce will last from four to seven years.

The Detroit United Railway Company lays narrow grooved rails in paved streets, the last laid being 90-pound rails. Some of the first experiments in the United States with tracks supported by concrete stringers instead of ties were made in Detroit. The first construction of this kind was laid on concrete stringers only 6 inches thick, but as these were not strong enough to support the rail, the present construction uses concrete stringers 12 inches thick by 18 inches wide. The concrete stringer is brought up around the web of the rail high enough to permit brick paving to be laid with only a thin cushion between the paving bricks and the concrete. The upper part of the stringer is continuous with the concrete foundation of the asphalt or brick paving, and no trouble is now experienced from lack of sufficient support. For holding the track to gauge, a wooden tie is now placed every 30 inches, whereas formerly a metal tie was placed every 10 feet. The present construction, therefore, with its closely spaced ties, is regarded as a partial abandonment of the plan of depending entirely on concrete stringers for track construction.

The Indianapolis Traction and Terminal Company has two standards of track construction in paved streets, one employing 93-pound girder rails for streets where only city cars will pass, the other a special 91-pound rail, which is a high T rail with a wide head, designed to be easily paved to and yet permit the passage of interurban cars with deep wheel flanges, of which there are now a large number entering Indianapolis over the city tracks. The standard rail for this service is 7 inches high, and has a head $2\frac{3}{4}$ inches wide to reduce the amount of overhang of the wide tread interurban car wheels. For outlying unpaved streets 70-pound A. S. C. E. standard 5-foot rail is laid. The standard tie is 6 inches by 8 inches by 7 feet white oak, laid 2 feet 2 inches between centers and ballasted with gravel concrete, which extends 6 inches under the tie, surrounds it, and is brought to within $4\frac{1}{2}$ inches of the top of the rail. Some track has also been laid on ties spaced 10 feet between centers, with a concrete beam, 20 inches wide and 9 inches deep, under the rail, and extending to within $5\frac{1}{2}$ inches of the top of the rail. The standard bonds are the protected, 10 inches long, placed under the fish plates, and No. 0000, 28-inch wire cable bond, placed over the fish plates. The bonds are applied with a screw compressor. The track is cross bonded every 500 feet between the rails of one track, while at every 1,000 feet there is a cross bond connecting the four rails of the double track.

The Milwaukee Electric Railway and Light Company succeeded some time ago in securing the approval by the city authorities of T rail construction for paved streets. A special new design of T rail, which is 7 inches high, with a head no less than 3 inches in width, has been adopted as the standard, so that, in the future, interurban cars using the city tracks may be equipped with wheels having treads and flanges more nearly approaching the standard steam railroad wheel tread. With a rail having the head 3 inches wide, a car wheel with a tread $3\frac{1}{2}$ inches wide could be used without having the wheel seriously overhanging the rail and bearing on the pavement. In asphalt or brick pavement, track is laid on ties 6 inches by 8 inches by $6\frac{1}{2}$ feet, placed every 2 feet with 6 inches of concrete tamped under each. As this rail has a very broad base, tie rods, which are liable to cause a weak spot in the paving, are not needed. The joints, rectangular in form, are cast welded. In asphalt streets, granite toothing blocks are laid alongside of each rail, for while the city pays for the original laying of the pavement, the company pays for the maintenance of the pavement between its tracks and 12 inches outside its tracks. Granite toothing blocks extend out 12 inches, or to the limit of the distance that the company must maintain paving. On unpaved suburban roads 75-pound A. S. C. E. standard T rail is laid.

The Twin City Rapid Transit Company, of Minneapolis and St. Paul, was one of the first to lay a T rail in streets paved with asphalt, where girder rail had been the rule before. The rail used is 8-inch T, weighing 79 pounds to the yard. The base of the rail rests directly on a concrete beam 22 to 24 inches wide and 12 inches thick under the rail. Around and above the base of the rail is placed 3 inches of natural cement if the paving is of brick, and less if the paving is of granite. A cast welded joint of somewhat unusual shape, 16 inches long and weighing 190 pounds, extends out from the head of the rail so as to make a substitute for paving at that point. A flange way on the inner side of the joint gives the effect of a grooved rail at the joint. The object is to facilitate paving around the joint and to provide against a weak point in the paving. The rails are in 60-foot lengths. The spaces between and around the paving blocks are filled with Portland cement grout, and fourteen days are allowed for the concrete to set thoroughly before any traffic is permitted. In less substantially paved streets, ties 6 inches by 8 inches by 8 feet, spaced 2 feet between centers, are used. A 6-inch concrete base of natural cement is placed between the ties and around their ends, and on this a sand cushion is spread. The brick or stone paving is set and grouted with Portland cement. For suburban construction a 5-inch 80-pound A. S. C. E. standard T rail is used, with ties 6 inches by 8 inches by 8 feet, spaced 2½ feet between centers.

The Philadelphia Rapid Transit Company uses for its standard track construction in streets having heavy traffic a grooved rail which weighs no less than 137 pounds to the yard, but where the traffic is lighter a section weighing 93 pounds is found sufficient. The latter style is also in use for suburban service where the streets are paved, while for unpaved suburban streets A. S. C. E. standard 90-pound T rail is used. In paved streets track is now being laid on concrete stringer construction, with chairs spaced 5 feet apart and a steel tie used in connection at every second chair, or every 10 feet, provision being made on these chairs for the adjustment of the gauge. A concrete stringer 17 inches wide extends 15 inches under the base of the rail. The foundation of the paving between the tracks is a bed of concrete 6 inches thick. All rails are laid with broken joints. A zinc joint used by the company consists of rolled steel joint plates surrounding the rail web and base, between which and the rail a filling of zinc is poured. Track construction hitherto has been laid on ties 5 inches by 9 inches by 8 feet, spaced 2 feet between centers. Where zinc joints are used no bonds are necessary, but on other track a protected form of bond, about No. 0000 wire, is used.

The Pittsburg Railways Company uses a 90-pound girder rail, in 60-foot lengths, laid on ties, resting on a foundation of broken stone. This foundation is in two layers, the upper layer being in 12-inch and the lower layer in 3-inch cubes, and extends to a depth of 21 inches below the top of the rail. Ties are 6 inches by 8 inches by 8 feet. Concrete is used around the rails to fill in the space between the head and base, the rails being laid directly on the ties and tie rods used. Cast welded rail joints are now being laid, the ties spaced 2 feet between centers. For suburban service 80-pound T rail and 78-pound girder section have been used.

The standard rail of the United Railroads of San Francisco for basalt block pavement is a 109-pound 9-inch girder, with ties placed 4 feet between centers. For streets paved with bitumen on a concrete foundation a 7-inch girder rail weighing 100 pounds to the yard is used, though for suburban service a 70-pound rail is the standard. The track is laid on ties 6 inches by 8 inches by 8 feet, with 3 inches of ballast under the ties except where concrete is used, when 4 inches of ballast is required.

The St. Louis Transit Company uses a concrete beam under each rail, with a concrete stringer 8 by 18 inches. To hold the track to gauge, a tie rod is placed every 6 feet, clamped to the base of the rails to prevent all tilting. The foundation of the pavement, the bottom of which is flush with the base of the rail, is a bed of concrete 6 inches thick, on top of which the asphalt is placed. The standard rail for city use is a 9-inch grooved rail, either 100 or 98½ pound section, while for suburban service the company uses a 95-pound 9-inch girder rail, and in dirt streets ties are laid to support the track.

Bonding.—It will have been noticed that frequent reference has been made to the subject of "bonds," which constitute so important a part of the system and circuit structure in electric railway work that it would be improper to pass them over without some explanatory comment. It is well understood that the current delivered to a trolley system reaches the car motor by means of feeder and contact wires, and that the circuit back to the power house is completed through the wheels and the track itself. If there were no such circuit completion, current would not flow, and it is therefore an essential and fundamental condition that both the feeding circuit and the return circuit should be maintained intact at all times with the least possible resistance to the flow of the current and also with the least opportunity for the current to leak away. The danger of leakage is particularly great, since the rails generally lie in earth, liable at all times to be more or less damp, and being adjacent to great masses of metal in the shape of gas pipes or water pipes, etc., which would furnish a better path than the rails for the current. Such pipes are liable to be attacked by a disease known as "electrolysis," which means, in this case, the corrosion or eating away of the iron or lead by the current.

It will be seen that with the traction rails broken at joints every 30 or 60 feet, some auxiliary device is necessary in order to make them continuous as a circuit. As even the most exact butting or overlapping of joints was found to develop abnormal electrical resistance, this condition was dealt with in the early stages of the art, and the problem was attacked in various ways. At the time of the street railway census of 1890 one method in vogue was to use the rails of the track exclusively, riveting to the rails around each joint a No. 6 galvanized iron bond. Another method was that of laying an auxiliary copper wire of the same size as the overhead trolley wire down the center of the track, on top of the cross ties, and connecting it with a wire of small size riveted to the center of each rail. As to the first method, it was soon found that galvanized iron bonds disappeared under the exposure to action in the earth, and the rails were rebonded with copper bonds riveted to each rail.

It was then discovered that these bonds were too small and that there was considerable loss of potential power because they deteriorated and broke off, so that it was again necessary to go over the lines and rebond them with heavier material. In the same way, owing to improvements in the method of bonding at the joints and the rapid adoption of heavier rails giving more conductivity in the return circuit, it was found unnecessary to incur the initial expense of auxiliary copper ground wire, and so the use of this was also given up. From that time on there has been a remarkable improvement in the matter of bonding the tracks, and a large variety of bonds have been put into service, usually of solid or stranded copper, but including some of a plastic nature. Among those favorably known and largely in use is the protected type, in which the copper bond, owing to its liability to be stolen, particularly on suburban roads, is protected or concealed and goes in the space back of the fish plate, against the web of the rail. The rails themselves, if their connection was unbroken, could, of course, carry the current of the return circuit without trouble, but as there are from 176 to 352 joints in a mile of track, at any one of which the circuit is liable to break, it is evident that bonds can hardly be used too liberally, while there is even warrant for supplementing the return system with return feeders, which may be carried either underground or on the poles supporting the overhead wires. Some railways have supplemented their track return by inserting into the return circuit a quantity of their old rails which have been scrapped and which can thus be utilized again to advantage. By methods of this kind the street railway companies have not only done much to lessen the annoying disturbance of adjacent telephone circuits experienced in the early days of the trolley, but have obviated quite successfully the electrolytic action on iron and lead pipes in the ground, caused by the current escaping from inadequate return circuits. No small amount of litigation and some very extensive and costly experiments have attended this work and development. The extent to which current can leak from a track may be inferred from the estimate that in ordinary double track the surface exposed for leakage is sometimes as great as 50,000 square feet per mile of route.

Despite the many bonding devices, a good many engineers give their preference to a track which is practically jointless. To secure this result two principal methods have been in use. One of them is electrical, and consists in welding the rail joints and plates together in some such method as that described on page 175 in connection with the track of the Buffalo street railway system. Another method often used consists in casting a sleeve of iron around the ends of the rail joints at the side and bottom. The sleeve is made of cast iron, of special chemical composition, which has been "run" at a much higher heat than is employed in making ordinary castings. The metal is poured in from one side and comes in contact with the web of the rail at its greatest heat. It brings the thin part of the rail to a white heat and tremendous pressure is exerted on the molten cast iron, which is squeezed into the interstices of the steel rail, becoming such an integral part of it that if a joint of this kind is sawn through it is impossible to say where the web of the rail ends and the cast joint begins. These joints are usually about 14 inches long and weigh from 70 to 140 pounds per joint, depending upon the size and weight of the rail that is welded. A very good mechanical joint is thus effected, and the electrical continuity of the circuit is high. A third method which has recently come into vogue consists in using a welding mixture known as "thermit," which is made of powdered aluminum and iron oxide. The combination of aluminum with oxygen evolves an immense amount of heat, and this reaction has recently been brought under control. A welding portion of the mixture is poured into a small crucible at the joint with a thimbleful of ignition mixture added, and the whole is ignited. The reaction is immediate, and the molten thermit flowing into the mold around the rail makes the joint.

It may be here noted relative to the details given of track bonding, that according to the statistics in Table 94, 1,642.68 miles have been constructed with cast welded joints. This method constituted only a small proportion of the entire mileage, leaving practically all the rest of the track rendered conducting and continuous by means of electrically welded joints or by the very generally used copper rail bonds. The cast welded track is found in a number of states, but particularly in California, with 110.62 miles; Illinois, with 292.68 miles; Minnesota, with 89.57 miles; Missouri, with 376.07 miles, practically all in St. Louis; New York, with 222.82 miles, virtually all in Buffalo and Greater New York; Ohio, with 129.85 miles; and Wisconsin, with 141.25 miles, all of which is in Milwaukee. It will be gathered from these figures, therefore, that cast welding is still limited to a few of the larger cities and urban systems.

II.

RAILS AND CONDUITS.

In Table 94 detailed statistics are given regarding the weight of rails per yard, the style of rail, and the method of rendering the track a perfect return circuit by means of cast welded joints. Considerable discussion of rail will be noted in the preceding section of text. With regard to the style of rail employed there is no uniform practice. Of the 817 operating companies, 367 used T rails exclusively and 390 reported the use of T rails in connection with girder, groove, or full groove rails. The range in the weight of the rail as shown by the returns is also quite remarkable—from the 15-pound T rail of the little Paso Robles, Cal., animal power system to the 135-pound girder rail used on the Union

Traction system in Philadelphia. A number of roads have rails of very heavy section, as, for example, 128-pound on the road of the United Railways and Electric Company of Baltimore; 120-pound on several roads in Louisiana; and 113-pound, 110-pound, and 109-pound on various roads. As might be expected, the T rail is a common form in interurban work associated also with lighter weights of 60-pound or 70-pound, but it is also to be found in urban limits. In Vermont all the rail reported is of T type and none of it exceeds 60 pounds in weight. In Texas also nearly all the companies report the use of the T rail, although in Houston, girder rail up to 96 pounds per yard is in use. A good deal of T rail of light weight is also reported from California, Colorado, Connecticut, Georgia, Illinois, Indiana, Iowa, Kentucky, and Wisconsin. Girder rail, on the other hand, is reported very generally, as will be seen from the table, in Illinois, Maryland, Massachusetts, Missouri, New Jersey, New York, Ohio, Pennsylvania, and Virginia.

Third-rail systems.—The number of companies operating by the third-rail system were so few at the time of the report, that it was not deemed necessary to make a separate section of the schedule for this information. Eleven companies in five different states, with a total of 342.11 miles of track, reported this form of construction. There is no third-rail construction within city limits on the streets, but there is considerable of it on the elevated roads of New York, Chicago, Boston, and Brooklyn. The Northwestern Elevated, South Side Elevated, Metropolitan West Side Elevated, and Lake Street Elevated, all in Chicago, Ill., report the third rail, with a total of 107.96 miles of third-rail track. In New York state, the Manhattan Railway Company, at the time of the report, was operating 40 miles in New York city by the third-rail system, but since that time and during the compilation of the report the whole of its 117 miles has been converted to third rail. The Brooklyn Rapid Transit Company reported 50.40 miles of track operated by third rail. The New York, New Haven and Hartford Railroad reported not less than 25.43 miles in Massachusetts, this being all on the surface and constituting an important electrical adjunct to the steam locomotive service of the company in certain limited districts. The Boston Elevated reported 16.02 miles of track with third rail. Besides this use of the third rail within city limits the report shows, even in 1902, a considerable amount of third rail on the surface for interurban purposes, similar to that quoted in Massachusetts for the New York, New Haven and Hartford system, which had 25.89 miles of this type of track in Connecticut on its Berlin section. At the time of the report California had no third-rail interurban road, although some was then under construction and has since gone into operation. In Michigan the Grand Rapids, Grand Haven and Muskegon road reported 36.63 miles of third rail. In New York state the Albany and Hudson Railway and Power Company reported 39.78 miles between the two cities named. This road runs through several communities of good size, where the third rail is safeguarded and has not been found any hindrance to general movement of vehicles or pedestrians. The trolley is used, however, in the terminal cities.

Conduit systems.—In connection with the treatment of roadbed and track must be considered the subject of conduit railways, since the modern conduit in electric systems, as in the preceding cable systems, constitutes practically a part of the structure. The earlier cable work in the United States was put in with a deep conduit or tube between the two rails. The conduit at San Francisco was 32 inches in depth, and that of the Chicago City Railway 36 inches. Such construction was expensive, not only on account of the excavation required, but because of the interference of the conduit with other subsurface structures. In constructing the conduit in natural soil it was necessary either to cut a formidable trench with pick and shovel or else to blast out the bed, and, on the other hand, if the line were built upon made ground, concrete foundation piers and sometimes even piles were necessary. In cable railways a grip extending down between two slot rails seizes a traveling cable, and the car is thus drawn forward, although it has no power of going backward. Many objections were urged against the system on the score that the slot caught the narrow tired wheels of passing vehicles, and that the conduit space constituted an additional gutter which it was difficult to cleanse; but the conduits were gradually made shallower, methods of removing mud and water were perfected, and the cable system had reached a high stage of development when electric traction became commercially feasible.

Having in mind the objections urged against the slot and conduit, much ingenuity was bestowed by electrical inventors on the development of electrical methods which would dispense with any such openings, but which would still bring the current to the car by means of conductors buried in the ground, in order to avoid the erection of overhead wires. These closed conduit systems have depended broadly either upon a third-rail conductor, or upon exposed knobs or contact buttons in the street bed, with which the moving car could make contact by means of a long "skate" or shoe. The section of conductor immediately adjacent to the car, electrified at the time the car passes it, becomes dead as soon as the car passes on to the next block or succession of contact devices. The connections are made by section switches, closed and opened by magnets carried on the car; auxiliary circuits, closed by the car itself as it proceeds; mechanically, or in a variety of other ways. This contact material has consisted sometimes merely of iron filings within the road contact plate. Sometimes the contact devices have consisted of plungers making contact through mercury cups at the switch box. The only contact system of this general character now in operation in the United States is that which has been installed by the Westinghouse Electrical Manufacturing Company in the United States Navy proving grounds at Indian Head, Va., on the Potomac. This line is about 3 miles in length, is operated in part by an overhead trolley; but, as the track crosses the firing line, where the overhead wires are liable to damage by projectiles, some other system was necessary, and the contact system has been adopted. Each car is operated with two steel contact shoes, and these shoes project downward from the bottom of the car by springs, energized by storage batteries on the car, make contact with successive pairs of pins set along the track. The switch boxes and contact pins are made as a complete unit, and the contact pins, where the boxes are installed upon the track, stand up 1½ inches above the running rail. As the car runs along the track the shoes "cut in" and "cut out" the pins so that only the portion of track over which the car stands is alive.

On the whole, therefore, it will be understood that surface contact street railway methods with closed conduits are not in vogue, and that where the overhead system is not allowed the open conduit method is the only one left permitting the use of electricity in large cities. The one other plan of bringing the current to the street car is that which is known as the third rail; but the inapplicability of this needs no discussion, the third rail being available only upon underground roads, elevated roads, and cross country lines with a more or less uninterrupted right of way. According to the returns presented in this report, of the 21,914.01 miles of single track operated by electric power, 97.2 per cent obtains current by means of an overhead wire. Deducting the mileage operated by third-rail and storage-battery systems, this leaves 1.2 per cent for the open conduit. But it is a superficial indication of the relative importance of the conduit, as it is only to be found in a few cities of dense population and extremely heavy traffic, such as New York and Washington. In both these cities the open conduit electric method has not only been applied of late years to lines of thoroughfare previously unoccupied, but has replaced entirely the cable conduit in leading streets, the most conspicuous example being Broadway, New York city.

One of the serious limitations of the open conduit method is its heavy cost of construction as compared with the overhead method. Detailed figures presented by Mr. A. N. Connett as to the Metropolitan Railway Company, of Washington, D. C., give a total construction cost of not less than $50,000 per mile of track, and the data given by Mr. W. C. Gotshall as to the total cost per mile of single track on the Second Avenue Railway, of New York city, showed a cost of about $58,000. Even this is far from the extreme cost reached on some lines. The real cost depends in very large part upon the amount of underground piping to be disturbed.

As there is a strong family likeness to-day among the various open conduit systems, a description of the Washington system may be taken as giving a typical view of intelligent work, although this system is not the latest in construction. The conduit, formed entirely of Portland cement concrete and resting on a concrete paved base, extends the entire width of the roadbed and 2 feet outside the outer rails. The conduit yokes go down 31 inches from the grade or surface, and the inside depth of the tube is 25 inches. At intervals of 13.5 feet manholes are provided for access to the underground work, and every 400 feet there are hatches by which the conductor rails, 27 feet long, can be inserted or removed. The conductor rails, along which the contact plow makes rubbing contact as it travels, are carried on porcelain insulators 4 inches in diameter and 7.5 inches deep over all, which are held by an iron cap and which support a bolt to which the conductor rail parts are attached like the lower horizontal member of the letter L. The conductor rails are of mild steel weighing 23.5 pounds to the yard—a weight which gives abundant conductivity for the current required to operate all the cars on the system at any one time—and are bonded together with copper bonds. It will, of course, be understood that the traction rails on the surface of the street are no part whatever of the electric conducting system, as they would be in an overhead trolley road. The slot rail of the track, weighing 67 pounds to the yard, is the same as that used on cable roads, except that a little more care is taken to provide for drainage of water from the edge of the slot. Careful provision for drainage is made within the conduit through manholes connecting with the sewer pipes about every 400 feet.

It is not to be understood that this system is general, as each conduit road has peculiarities of its own, and the same road will show modifications in conduit structure on different sections. The Lenox avenue conduit structure in New York city, which is one of the best known of the pioneer systems, began by carrying its insulators and contact rails on pedestals standing up from the base of the conduit, but these were early abandoned, and on the road as now operated the insulators and contact carriers are inverted and supported from the conduit roof, somewhat as in Washington. One of the governing conditions has been the retaining or replacing of the old cable conduit, the new electric conduit methods being modified in the former case, as upon the Third avenue line in New York city. Upon the newer sections of the Third avenue line the conduit yokes were placed 5 feet apart, and built up of three pieces riveted together, namely, a steel I-beam weighing 105 pounds, and two cast-iron side pieces weighing 122 pounds each. These yokes are planted in a 4-inch bed of concrete, and the conduit between the yokes is of solid concrete. The slot rail, weighing 66 pounds to the yard, is laid in 30-foot lengths, while the track rail of the girder type, 9 inches high and weighing 107 pounds to the yard, is laid in 60-foot lengths. The steel conductor rail, weighing 21 pounds to the yard, is carried on inverted insulators hung from inside the slot rails.

This construction, however, is not to be regarded as standard—a word which would apply better to the practice adopted in 1897 in New York, and which has been followed in the construction of the conduit system at Brussels, London, and other foreign cities, although in several of the European cities conduit is laid under one of the rails instead of between them. Another point of difference relates to the plow rather than the conduit; thus the contact shoes used in Brussels, instead of being pressed outward horizontally, as in the New York and Washington plows, are swung out vertically in the arc of a circle, the arc being 135 degrees. Another variation in this detail occurs in Vienna and Budapest, where the plows are hinged from above and swung around in an arc of about 45 degrees. A further point of difference which is interesting to notice is that the rubbing surface of the contact device is on top of the contact rail instead of on the face or side, as in other conduit systems.

The old method was to build up the conduit from the bottom of the trench. The new method of conduit construction, as distinguished from the old, is to build downward from the slot and track, which are first aligned with the conduit yokes, the cement being then packed around a movable mold. A few words of description as to the present method, followed in New York and Europe, are given below.

A trench is first constructed of exactly the dimensions which will be taken by the completed conduit, so that the quantity of earth removed is a minimum. The yokes are placed about 5 feet apart in niches, which are carefully cut in the trench at exactly the points required. After this has been done, wooden timbers are placed across the trench to support the slot rails, at such a height that the slot rails, when placed on them, will rest on the yokes, and will be in their proper future positions. On these timbers are mounted cast-iron clamps, of just the right shape to fit and hold the base of the slot rails. The rails themselves are then set in these clamps, and joined at the top by means of a T-shaped clamp, which embraces the heads of the rails and fits into a mortise in the lower clamp. In this way the proper position of the rails is secured, and it is only necessary to align and level them by adjusting the position of the wooden timbers. In other words the track is aligned by means of the slot rails, which is the end desired, and the rest of the structure is made to conform to it. The yokes are next attached to the slot rails by means of four bolts for each yoke. The brace rods are then put in place connecting the yokes with the web of the slot rails. The only work now remaining to be done is to build up the conduit proper.

Exposed, as the conductors in an open conduit are, to all the vicissitudes of weather, it is natural to expect that they would be liable to frequent interruption on account of the burning out of sections by short circuiting, which easily happens when moisture is present. On the whole, however, the operation has proved extremely satisfactory, and the conduit and track conditions have been far less susceptible to trouble than was expected. In fact a more sensitive and weak part of the system has been the contact plow. It is not only subject to considerable wear, but may become jammed in the slot, especially if a car should happen to get into collision with other vehicles. The applicability of the method, as well as the practical verdict upon it, is to be found in the fact that not only has it superseded the cable in New York, but it has also replaced the storage battery, and is being installed on several of the branch lines where horses are still in use, so that ultimately the whole of the city below One hundred and thirty-fifth street will depend upon the open conduit for its surface street railway transportation.

III.

ELECTRIC LINE CONSTRUCTION.

The importance of overhead trolley construction for the operation of electric railways may be deduced from the fact that of the 21,901.53 miles of track operated by electric power embraced in this report, 21,290.09 miles received the current for the cars by means of overhead wires. From the details of electric line construction, shown in Table 94, it will be seen that of the total, 15,857.26 miles, 10,220.07 miles, or 64.5 per cent is span wire; 5,223.08 miles, or 32.9 per cent, side bracket; and 414.11 miles, or 2.6 per cent, center pole. It also appears from the returns that wooden poles have been used for 80.3 per cent of this mileage and steel or iron poles for 19.6 per cent. In addition to this, 15.92 miles of line have wires supported by elevated railway structures and by buildings or bridges. The same table shows for each railway the number of poles to the mile, the average being about 52, ranging from 40 up to 75, depending upon the local conditions and requirements. The extreme figures are 30 poles to the mile, reported for the Salem Electric Railway Company, of Salem, Ohio, and 85 reported by the Duluth-Superior Traction Company, of Duluth, Minnesota.

Span wire construction.—Table 94 shows that the span wire construction reported—10,220.07 miles, or very nearly half of the overhead trolley construction—was very largely in the cities. Thus in California, with a total of 339.82 miles, 98.66 miles was reported by the United Railroads of San Francisco; 55.82 by the Los Angeles Railway; and 66.43 by the Oakland Transit Consolidated Railway. These three companies constitute a very large proportion of those of the same character within the state. In Colorado, out of the 140.16 miles, 82.02 miles was reported by the Denver City

Tramway. The state of Illinois reported a total of 799.06 miles of span wire. Of this mileage nearly half was reported in the city of Chicago. In Indiana, out of 357.80 miles, 127.40 miles was reported by the Union Traction Company of Indiana, and 36.39 miles by the Indianapolis Street Railway. In Massachusetts, with a total of 712.85 miles, a group of three roads in and around Boston—the Old Colony, the Boston and Northern, and the Boston Elevated—reported 445.50 miles. In Ohio this style of construction appears to be generally distributed, but out of the 908.56 miles, 115.41 miles were reported by the Cincinnati Traction, 69.31 miles by the Cleveland Electric Railway, and 47.87 miles by the Cleveland City Railway. In Pennsylvania, with a total of 1,532.83 miles, the Union Traction Company, of Philadelphia, reported 308.86 miles, and the Pittsburg Railways Company, 232.09 miles. It will be gathered from the foregoing figures, therefore, that the span wire construction is to be credited with a larger track mileage than would appear on a superficial reading of the figures. In other words, there was a total mileage reported of overhead trolley construction of 21,290.09 miles, but there was only 5,223.08 of side bracket and 414.11 of center pole. These two items made a total of 5,637.19 miles, which would leave a total of 15,652.90 miles of overhead construction to be accounted for, whereas the mileage of span wire reported was, as already noted, only 10,220.07 miles. Allowing that all the center pole construction covered two tracks, and that part of the side bracket also had long brackets, enabling two tracks to be served, it would still appear that half of the span wire construction was employed to cover double tracks. This applies to the construction in many cities, as, for example, Chicago, Ill.; Indianapolis, Ind. (almost entirely); Minneapolis and St. Paul, Minn.; Omaha, Nebr.; Brooklyn, N. Y.; and Cincinnati, Ohio.

Side bracket construction.—The side bracket construction counts, of course, for every mile of track over which it extends, and in some cases, as has already been noted, covers the two tracks, the detailed statistics being, however, difficult to extract where all the methods of overhead construction were employed. Side bracket construction is obviously an adequate and satisfactory method for suburban and cross country lines where but one track has to be served, and hence, as might be expected, a large amount of this mileage, namely, 5,223.08 miles, is to be found in states and along roads where the single track is more prevalent. The state of Maine is notable for the large amount of side bracket construction which it contains. With a total of 328.55 miles of overhead construction, there was not less than 240.16 miles of the side bracket type. Massachusetts also had a very large proportion of side bracket construction, even in such crowded centers as Boston and vicinity. The Boston and Northern system reported 182.53 miles, and the Old Colony Street Railway 228.69 miles. Out of the 75 roads or systems reporting for the state, 16 reported only the side bracket form of construction. In New York state the side bracket form of construction was not so conspicuous, only 453.04 miles being reported, and of this 82.63 belonged in one system, that of the Hudson Valley Railway, while Rochester and its suburbs presented another large group of the same style. The Rochester and Sodus Bay Railway had no span wire, but 34.86 miles of side bracket and 4.44 of center pole. The state of Ohio, as might be expected, with its interurban groups, had a large amount of side bracket construction, namely, 936.35 miles, which was very widely distributed. As previously noted, Pennsylvania had proportionately little side bracket construction, although several of its roads were extensive suburban systems. The state of Vermont, in the New England group, is noteworthy for its large proportion of side bracket, as will be seen from the table.

Center pole construction.—The center pole line construction for the whole country, 414.11 miles, should normally represent exactly twice that amount of track served, since the invariable purpose of such construction is to serve two tracks with one line of poles, by running a line of poles down the middle of a wide thoroughfare between the two tracks. Very often this center pole is masked by shrubbery, and one of the earliest and best instances was the line put in at the beginning of the trolley régime by the Washington road running out to Eckington and the Soldiers' Home. This center pole construction is widely distributed throughout the country, as will be seen from an inspection of the table. Several states possessed 20 or 30 miles of such construction, while Maryland had 40.14 miles, and New York 32.41 miles—the latter being so widely distributed that only one road had more than 6 miles of it. It will be observed that few of the interurban systems report any considerable amount of this style of construction. The interurban system most conspicuous for its center pole construction was the Grand Rapids, Holland and Lake Michigan, which reported 24 miles. The Twin City Rapid Transit system of Minneapolis and St. Paul is conspicuous for reporting 60.50 miles of center pole construction, which represents 121 miles of single track, and would account for nearly one-half of the entire 251.02 miles of that system. In California the most notable instance was that of the Los Angeles Pacific Railway, an interurban system, which reported 20.65 miles of center pole, accounting for more than 40 miles out of the total of 87.48 miles of track.

Line supports.—Table 94 shows in detail, in terms of mileage, the statistics with regard to the use of steel or iron poles and wooden poles. It will be seen that 12,728.76 miles of track were reported as equipped with wooden poles and 3,112.58 miles with steel or iron poles, making a total of 15,841.34 miles, which apparently would represent the actual mileage of the streets and other thoroughfares occupied by the overhead construction. This mileage, however, has no definite reference to the miles of track, as such, whether single or double, as a mile of overhead construction might obviously be inclusive of both conditions and methods. The metallic pole, although its use is quite widely distributed, is not found in some states. Illinois reported 264.35 miles; Massachusetts, 294.91 miles; New York, 485.28 miles; Ohio, 302.41 miles; and Pennsylvania, 540.20.

A study of the figures will show that the metal pole was used chiefly within city limits; thus, companies in Chicago, Ill., Detroit, Mich., Minneapolis and St. Paul, Minn., and Philadelphia and Pittsburg, Pa., reported nearly all of the metal poles shown for the states in which these cities are situated; and companies in St. Louis, Mo., Boston and Springfield, Mass., Cincinnati, Cleveland, and Columbus, Ohio, and New York city, N. Y., reported a large proportion of the metal poles of the states in which they are located. There is an aesthetic advantage in the use of metal poles, as compared with wooden poles, aside from their more sightly appearance, in that, on the average, fewer of them are required per mile of electrical construction. The number of metal poles per mile is usually from 40 to 50, though in some cases, as in certain places in Ohio, 60 or more poles per mile were reported.

With regard to the use of wooden poles, it may be noted that of the 12,728.76 miles equipped with such poles 1,724.64 miles, or 14 per cent, was reported for Massachusetts; 1,554.79 miles, or 12 per cent, was reported for Ohio; 1,452.19 miles, or 11 per cent, for Pennsylvania; and 1,047.20 miles, or 8 per cent, for New York state; these four states together, therefore, reported 45 per cent of the total for the country.

Feeder construction.—A large proportion of the feeder wire mileage was carried overhead and on the poles referred to above, and very little of it—2,411.07 miles out of 24,754.29 miles, barely 10 per cent—was underground. The use of the overhead method for feeder wire was so general that the exceptions alone deserve study, and these are presented in Table 94, which shows that the underground feeder wire mileage occupied 589.3 miles of street within city limits, in connection with some 27 of these railway systems, though these systems in some cases represent two or more cities. The largest amount of such underground feeder wire construction was found in three states, which together accounted for about 78 per cent of the whole, namely: Pennsylvania, with 204.8 miles of street and 1,685.8 miles of duct; New York state, with 145.8 miles of street and 3,317.1 miles of duct; and Wisconsin, with 110.8 miles of street and 674 miles of duct. In these three states the feeder conduit work was limited almost entirely to the three cities of New York, Philadelphia, and Milwaukee.

Further details of feeder construction are furnished in supplementary Table 2, which shows the statistics for the different kinds of conduit used. In this connection it may be stated that the cable most commonly used was copper strand, heavily insulated, and sheathed with lead, the copper conductor being further protected in some instances, as in New York, by special paper insulation. The largest proportion of feeder conduit was constructed of terra cotta and vitrified clay. The 336.6 miles of street occupied and 3,905.1 miles of duct, used by this kind of conduit, amounted to more than half of the whole conduit feeder mileage. Iron pipe conduit occupied 156 miles of street, with 1,981.4 miles of duct. Terra cotta and vitrified clay conduits were used exclusively in Wisconsin, while in New York and Pennsylvania iron pipe was also used, as well as a certain amount of wooden duct. New York reported the greater part of the 13.5 miles of street with concrete construction. As to wooden duct, out of 83.2 miles of street occupied by 565.1 miles of duct, 76.2 miles of street, and 542.5 miles of duct were reported from Philadelphia, Pennsylvania.

While it is urged by many who are interested in the aesthetic improvement of urban centers that the overhead network of a trolley road is ugly and an eyesore, it can not be denied that in this branch of the work a most marked and rapid improvement has been seen, both with respect to the appearance of the line and in regard to its stability. The early construction left much to be desired, and the materials used were altogether too light and cheap for the conditions imposed upon them, while a great many details now making for trimness and permanence had not been worked out. One of the greatest drawbacks was found in the fact that for some years it was considered necessary to put upon the poles, not only the small conductors with which the trolley wheel makes contact and the necessary supports, but also all the mains and feeders delivering current to the lines as a whole. In fact this practice still prevails to a considerable extent in regard to feeders, as may be inferred from the fact that of the 24,754.29 miles of feeder wire 22,343.22 miles, or 90.3 per cent, was overhead.

At the time of the report conduits for feeders were employed by only 27 companies, but the tendency to remove the heavy cables and conductors from the poles is becoming very marked, and in the next few years, especially within city limits, a very large proportion may be expected to be taken down and put out of sight. The fact that underground construction is still limited to a few cities is shown by the fact that Washington, Chicago, New York, Boston, Philadelphia and Milwaukee contained 6,136.3 miles of duct, or 93.7 per cent of the total in the United States.

Overhead trolley.—The construction of overhead systems has been greatly simplified since the time of the report on street railways for the census of 1890 by the general adoption of the single overhead trolley system, by means of which the track is used as a part of the return circuit to the power house, one overhead wire bringing the current to the motor. The double overhead trolley, which was often used before 1890, was soon found to introduce a great many serious complications. Not only do the two wires necessitate additional overhead structure and wiring to support them, but the cars must carry two trolleys. When the car has to pass switches and frogs, changing the direction of the overhead contact, a vast amount of complication ensues. In short, the difficulties and objections have been such that in 1902 only 7 companies reported the use of the double overhead trolley system, the total mileage of track thus operated being only 234.15. Nearly all of this was reported from Cincinnati, and all of it would be gladly discontinued by the companies but for purely local convenience or for the requirements of old ordinances and franchises insisting upon the maintenance of this method.

The nature of pole line adopted for overhead construction depends a great deal upon the width of the thoroughfare, the extent to which the district is built up, the style and quality of surrounding buildings, and the restrictions imposed by the public authorities. As has already been noted, a very large proportion of the construction is of the "span" type, which consists in setting poles along the street at regular distances in pairs, exactly opposite to each other, and then spanning the roadbed by means of a span wire. This is repeated at each of the poles, and the service wire, with which the trolley wheel makes contact, is attached to the span wire and carried along underneath by insulators. The span wire is necessarily strong and, as a general thing, consists of galvanized iron and steel stranded wire, an ordinary size being five-sixteenths of an inch. If the street is unusually wide, the size of the wire across the roadway and the two tracks may run as high as three-eighths of an inch, while on the other hand, quarter-inch wire will be used for a single track span. A large number of detail parts are necessary to insure solid and substantial suspension, and to prevent the possibility of breakdown, which would not only inflict injury on persons and property, but interrupt the operation of the road.

To quote specific examples, at Indianapolis, Ind., the size of the span wire varies from three-eighths of an inch to five-eighths of an inch, according to the width of the street and the strain imposed, and the trolley wire held up is No. 00 round wire, a strain insulator being placed in the span wire next to each pole. In St. Louis in the latest construction of span wire a 7-strand double galvanized steel wire five-sixteenths of an inch thick is used. The trolley or service wires are insulated by a joint strain insulator at the pole and by a trolley wire hanger with wooden insulation, a bolt in which a cone shaped piece of wood furnishes the insulation. The ear for holding the trolley wire is 15 inches long and is clinched or hammered in order to hold up the wire, no solder being used. In Milwaukee, Wis., a notable change from the ordinary line work has been the abandonment of insulated trolley wire hangers, those employed being entirely of metal. Insulation is secured by strain insulators in the span wire itself, of which there are two in series between the pole and the trolley wire. The trolley wire hanger is of the usual appearance, except for the omission of the insulating bolt, and being purely mechanical in its function and not requiring insulating qualities, it can be made very substantial. Another feature of the Milwaukee construction is that known as "figure 8" trolley contact wire, the wire in cross section resembling that numeral, allowing the ear of the insulator to clip the upper part more firmly. In Philadelphia, Pa., the practice differs from that of both St. Louis, Mo., and Milwaukee, Wis., in the fact that a round top bell trolley wire insulator is used with soldered ears 15 inches long and weighing 14 pounds. The Twin City Rapid Transit Company of Minneapolis and St. Paul, Minn., uses a trolley wire hanger of its own manufacture, in which the insulation is secured by a structure of wood supported in the metal from the bracket or span wire, in each end of which the trolley wire clips are supported.

In addition to carrying the span wire, which in turn carries the contact conductor, the poles, as has already been noted, have to support feeder cables, which are necessarily of considerable weight, usually being of copper, though aluminum is sometimes used. Moreover, the feeder cables carrying large quantities of current require extra large and heavy insulators, for which glass or porcelain is generally used, though sometimes a compound of mica and shellac, rubber, or asbestos is used. The feeder cable runs parallel to the track, and is tapped at frequent intervals in order to supply current to the different sections of the trolley system. These taps are made from the top of the pole across the span and connected to the trolley wire at numerous points. Sometimes these feeder taps are used as a span wire.

Nor are these wires and circuits all that go to make up the web-like network of wires which are seen above a trolley track, and more particularly above a double track covered by the span wire system. At corners and curves a large number of auxiliary span wires and brace and guy wires have to be introduced, all adding to the apparent complication of the system. In many places, moreover, local ordinances still require that guard wires shall be used above the trolley network to prevent broken telephone, electric light, or other wires from falling across the trolley system. Where these are added the result is usually very disagreeable to the eye. Street railway managers are decidedly averse to this addition to the wire structure, claiming that the guard wires rarely serve a useful purpose, and are more often the cause than the cure of the evils they are designed to obviate. A feature of span wire construction which is not uncommon in Europe, but which is hardly known in the United States, is that of carrying the wires across the street without poles, from building to building, attaching the span to rosettes of metal firmly embedded in the fronts of the houses. This method is frequently permitted by the authorities, and the entire absence of poles gives a much clearer vista to the thoroughfare along which the trolley system is in operation.

Next in importance to the span wire construction is that which is carried out by means of side brackets. The purpose of the side bracket or side arm construction is to decrease the cost of line construction as well as to lessen the number of poles along the street, it being feasible to extend the side arm from the pole to such a length as to carry the circuits for a double track system. The side arm projection from the pole is braced from below, and is also often supported from above, to insure rigidity. The methods of suspending the trolley service wires are much the same as with span suspension, the chief difference being, perhaps, in the insertion of insulating materials between the arm and the iron sleeve by which the insulator is carried.

Another variation in overhead construction is the use of the center pole, which is virtually a duplication of the side bracket pole, the arms being extended out on both sides of the pole, the pole being planted in the middle of the street or avenue, midway between the two tracks. With the center pole construction a greatly improved appearance of thoroughfares is often obtained. The center pole is also often utilized for lighting purposes, especially where the city ordinances require that a certain amount of lighting shall be furnished free by the trolley company in part return for its franchise; and some extremely pretty effects are often obtained, especially where the poles are of ornamental character. The center pole construction, however, is not favored, as it forms an obstruction to traffic, being in the center of the street.

Wooden poles constitute a very large proportion of the supports employed in overhead line construction. The greatest variety exists with regard to the nature of the woods used and the treatment adopted in preparing poles for use and in setting them. The wood favored depends very often upon the proximity to the forest where the poles are cut, but the kinds in most general use are chestnut, cedar, or Georgia hard pine. Chestnut poles are preferably of second growth, and are used up to a length of 45 feet. Cedar poles do not possess the elastic or tensile strength found in hard pine or chestnut, and are not favored in lengths over 45 to 50 feet on account of their liability to succumb to the strain of storms and the weight of conductors. In a general way the poles used are trim and straight, with a departure from the center line of not more than 4 or 5 per cent, and they are often trimmed and made hexagonal or octagonal in shape, as well as painted in some standard color adopted by the system.

On the suburban lines of the United Railways of San Francisco the standard type of pole is 30 feet long, 12 inches at the base, and 8 inches at the top, the material being redwood, which, of course, is hardly obtainable in other parts of the Union. On one of the systems in Brockton, Mass., most of the poles are of chestnut 30 feet in length, with 7-inch tops, set 5.5 feet in the ground, and carrying arms of Georgia pine, which are equipped with four locust pins to hold up the insulators and wires. On the Schenectady, N. Y., system, where the city overhead work is all span construction, 35 and 40 foot chestnut poles are used, set 100 feet apart. On the Ballston, N. Y., branch, the center-pole double-bracket construction is used, with 35-foot octagonal pine poles embedded in concrete.

The extent to which wooden poles have been used in this country is undoubtedly due in a large measure to the ease with which such poles can be obtained. In Europe, where wood is scarcer, the metal pole is much more generally used. It may be questioned, however, whether the use of iron and steel poles in this country would not make a much better numerical showing than it does were it not for the enormous extent of suburban and rural lines, of which wooden poles are so conspicuous a feature.

The iron and steel poles in use are tubular and are built up in sections to a height of as much as 50 feet. Of the sections, generally, three or four are used to a pole, with a cap and base, which in some cases are ornamental. Occasionally a metal pole is seen which is "built up," i. e., composed of several iron or steel channels joined together. Another variety of the metal pole is one that is made in one length and is seamless, constituting a solid drawn steel tube, although these are sometimes built up of two parts shrunk together. A standard American iron trolley pole with a length of 30 feet, built up in three 9-foot sections, weighs a little over 500 pounds. Some of the poles, however, are much heavier than this, and a standard pole of an all over length of 30 feet also weighs almost 800 pounds. The size and weight and ability to resist strain depends, in fact, very much upon the policy of liberality adopted by the company building the system. Where the pole is of the usual sectional type the various sections are sweated or welded together, and care is taken that the longitudinal seams in each consecutive piece are 120 degrees apart in order to increase the strength and distribute the strain, which with ordinary poles will reach almost 500 pounds, since in winter the poles frequently have to carry not merely the weight of the wires but an additional burden of ice and snow or sleet.

To take a few typical illustrations of current American practice, the Boston Elevated Company employs for straight work a three-section tubular pole weighing from 700 to 800 pounds with tapering sections 6.5 inches, 5.5 inches, and 4.5 inches in diameter. Even heavier poles than this are used where a greater weight of overhead structure has to be held up, these poles weighing as much as 1,050 pounds, while on curves the tubular poles reach a weight of not less than 1,450 to 1,500 pounds. In Indianapolis, Ind., the poles are in three sections, weighing 600 pounds for straight line work and 1,400 pounds at curves. In Milwaukee, Wis., the poles used for straight line work are 28 feet long, built up of two sections of tubular steel, 8 inches and 7 inches, respectively, in diameter, and set in concrete. In St. Louis, Mo., the standard poles for straight line construction are in 28-foot and 30-foot lengths, with a weight of 545 and 650 pounds, while on curves 1,025-pound poles are used.

IV.

BRIDGES, TUNNELS, AND CROSSINGS.

Bridges.—Supplementary Table 1 gives the statistics with regard to the number and length of the different classes of bridges. These data include only structures owned by the railway companies, and no statistics as to the number or length of structures employed by the street railway companies under lease or franchise or other condition of that character are shown. A total of 2,721 bridges with a total length of 461,109 feet, or more than 87 miles, is reported for the United States. Of these bridges, 1,024, with a length of 156,061 feet, were of iron and steel; 574, with a length of 57,152 feet, were wooden; 931, aggregating 242,458 feet in length, were wooden trestles or trestle bridges; and 192, with a length of 5,438 feet, were of masonry. It will be seen from these figures that wooden bridges and trestles predominate, but that the work is of a varied character and that already a large proportion consists of iron and steel. Some features of this work vie with that of the same character done on steam railroads.

An interesting example of bridge construction is found on the line of the Conneaut and Erie Traction Company's railway completed since the figures of this report were taken and therefore not embraced in the above totals. This road, which renders possible a continuous electric railway trip from Detroit, Mich., to Westfield, N. Y., traverses such rocky and irregular country that considerable cutting, filling, and trestle work was necessary. One of the most serious difficulties was that encountered near Conneaut, where it was found necessary to build a steel viaduct.

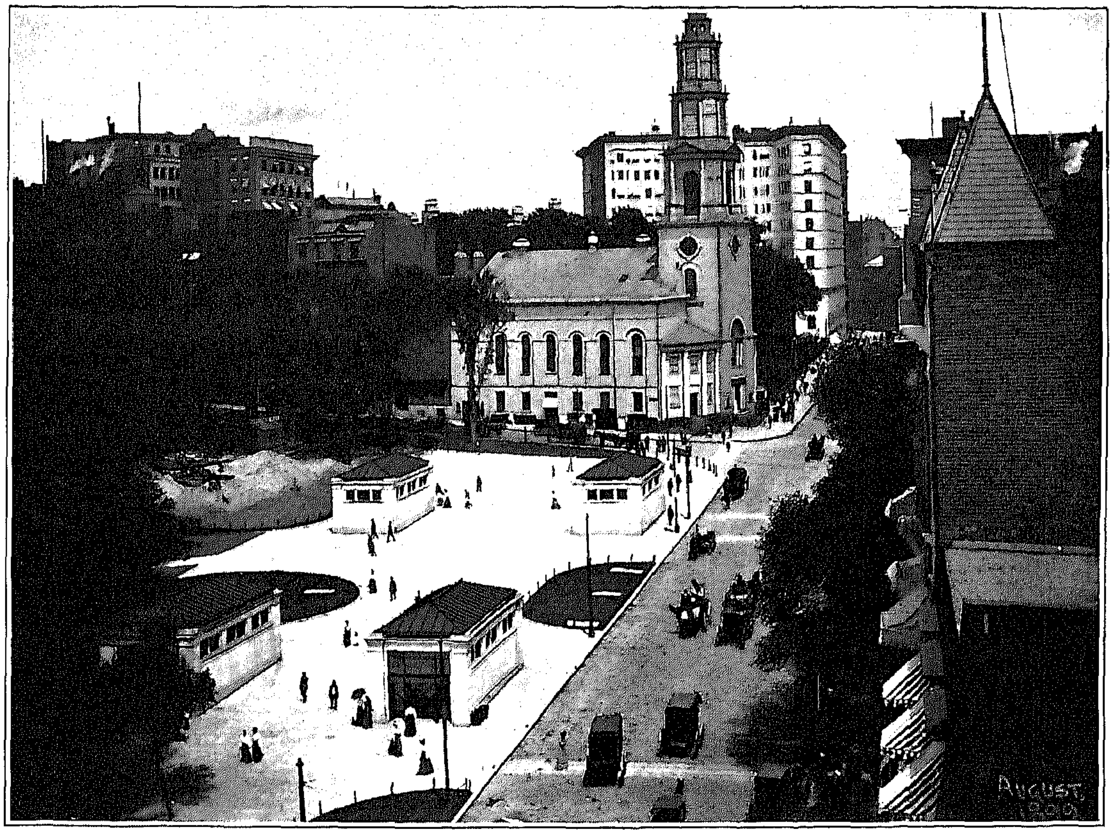
One remarkable instance of trestles built for trolley work and of wooden construction is the bridge owned and operated by the San Francisco, Oakland and San Jose Railway Company. As the statistics embraced in the table indicates, the street railways around San Francisco and Oakland have long stretches of wooden bridges and wooden trestles, probably rendered necessary by the shallowness of San Francisco bay and other local conditions. In addition to these is the double track trolley pier which has a total length of 16,400 feet, with 14,423 feet of tangent track on the pier, and a height of rail above high water of 7 feet 9 inches. Regular 4-car trains ply over this trestle. The overhead construction is of the regular trolley type with cross suspension wires.

Another example, the New Jersey and Hudson River Railway and Ferry Company, in New Jersey, embraces in its line a variety of interesting illustrations of the amount of work that a street or interurban railway may have to do in this category. An extension of this system, made in 1900, although less than 3 miles in length, includes a steel viaduct 1,150 feet long, with a 70-foot plate girder span over the Northern Railroad of New Jersey; a double trestle 580 feet long with 70-foot plate girder draw over the Overpeck creek; and a steel viaduct with a 500-foot plate girder span over the West Shore Railroad. The foundation of the long steel viaduct had to be laid in a marsh, and it is interesting to note that while the company found that the estimates for a wooden trestle were lower than for the steel, the latter was more desirable, not only on account of its durability, but in order to avoid the danger of destruction by fire, the marsh and meadow grasses often catching fire in the fall in such a manner as to jeopardize any construction of wood.

Another important and interesting example of such work is the swing draw across the Hackensack river, giving entrance to the town of that name. As this is one of the largest drawbridges in the country, if not indeed the largest, employed for electric railway work exclusively, it deserves note. The approaches to the draw are over trestles at each end, the western trestle being 915 feet in length and consisting of 61 bents of 15 feet each, while the eastern trestle is 285 feet in length and consists of 19 bents of 15 feet each. The swing or draw of the bridge is 160 feet in length, and is equipped with electric motors and trains of gearing so that it can be opened and closed in one and one-half minutes. The bridge is designed to carry a full load of 30-ton cars on each track.

In general, no figures with regard to elevated railroads and inclined planes are included in this table, although it might be claimed that these were wholly of a trestle character or in the nature of a viaduct. Elevated railroads, however, have been considered and treated sui generis, though some figures with regard to bridges employed by the Brooklyn Rapid Transit system in connection with its surface track have been included in the table.

Tunnels.—Supplementary Table 1 includes also data with regard to tunnels employed in connection with street railway work. There were 27 of these, with an aggregate length of 19,803 feet. Up to the present time street and interurban railway work has been almost entirely free from tunnel construction. On grades



TYPICAL ENTRANCES AND EXITS, BOSTON SUBWAY.

ONE OF THE PASSENGER STATIONS IN THE BOSTON SUBWAY.

where the heavier nature of steam railway traffic would have required tunneling, the lighter character of street railway rolling stock and the conditions under which the smaller number of passengers has to be carried have usually enabled the street railway systems to avoid tunneling. A large proportion of the track also is laid in cities and villages where tunnels are rarely needed. Interurban roads, however, sometimes operate under physical conditions closely resembling those that have governed steam railway practice, and a considerable development in the matter of tunneling may therefore be expected to attend the extension of interurban construction and the change in the character of electric railway service.

Of the total length of tunnels, 19,803 feet, reported for the country, a length of 16,285 feet, or 82.2 per cent, was reported from three cities, Boston, Chicago, and New York. In Chicago, where, on account of the extremely level character of the country, one would perhaps scarcely expect to find a tunnel, there are five tunnels, with a total length of 5,971 feet under the Chicago river. They were built years ago to avoid the delay that would be a necessary incident of the traffic if the cars were compelled to wait for the opening and closing of drawbridges. The Park avenue tunnel, in New York city, accounts for 1,800 feet of the tunneling reported in the table. This tunnel, which runs from a little south of Thirty-fourth street, through Fourth and Park avenues, to Forty-second street, is to all intents and purposes a steam railway tunnel, and for most purposes may best be regarded as forming a part of the system by which the New York Central and Hudson River Railroad penetrates to the heart of the city. Indeed, the street railway to which this tunnel belongs was formerly under Vanderbilt ownership, and was one of the traction lines out of which grew the New York Central system. The tunnel therefore represents steam railway practice rather than a practice made necessary by actual street railway conditions. The greatest length of tunneling shown for any one company, city, or state is that reported by the Boston Elevated Railway Company, Boston, Mass. The tunnel used by this company in its subway service is 8,554 feet long, and it represents one of the most interesting and important developments of recent years in street railway work, marking perhaps a transitional stage in street railway operation. It lessens the congestion of traffic on the streets, while at the same time it obviates the need of resorting to a deep underground railway, like that now under construction in New York city. Indeed, it seems to have served its purpose admirably in almost every respect.

This tunnel system was laid out and carried through by what is known as the Boston Transit Commission, a body still pursuing further useful work of the same kind. After a preparatory period of several years the subway became available to the public in 1897. In a general way, the subway may be said to traverse the city from north to south, with a westward spur under the Boston Common and the Public Garden, the northern limit being the Union Station and the southern limit being in the vicinity of Tremont street on Boylston street. The street railway lines enter the heart of Boston from the north, west, and south, the east being water front. A majority of passengers leave the cars before or upon reaching the termini of the lines on the edge of the business section, but a large number find it necessary to continue their journey across and through the city to other districts or suburbs, and the subway meets their need for quick transit. Since the tunnel went into operation the original plan of the commission, that the subway should be used only for cars of street railway types, in single or two-car trains passing from the surface tracks, has been modified to permit the running of elevated railway trains through the subway from the elevated tracks of the Boston Elevated Railway Company.

The original contract for the use of the subway made between the commission and the West End Street Railway Company provided for the payment to the city of a fixed annual rental equal to 4⅞ per cent on the cost of the subway, payable quarterly, and for a further contingent payment to be determined as follows: All cars of a body length of 25 feet or less were to be reckoned as paying to the city a rate of 5 cents per car per one-way trip, longer cars to be rated proportionately; and if the amount so computed should in any regular three-month period exceed one-fourth of the rental payment mentioned above, the West End Company was to pay such excess, in addition to the fixed quarterly payment. During the quarter ending March 31, 1902, the company ran 1,038,097 one-way trips through the subway, estimated on the basis just explained. The cost of the subway to September 30, 1902, is set down as slightly over $4,000,000. A rough calculation shows, therefore, that the excess on contingent payment for the quarter must have been more than $2,000, the fixed payment being taken as about $49,000. The rental is based on a twenty-year lease.

Two types of construction were adopted for different sections of the subway. One consists of steel I beams, embedded in concrete, supporting a roof constructed of transverse steel beams or girders with brick or concrete arches between them. The standard height of this construction is 14 feet clear, above the top of the rails, the width of two tracks being 24 feet and of four tracks, 48 feet. The four-track subway has a line of steel posts along the center. The top of the rail is about 17 feet below the surface of the street and the station platform about 16 feet. The second form of construction consists of masonry side walls and a masonry roof. This form was adopted where the tunnel could be placed at a sufficient depth below the surface to make possible adequate provision for strength and stability by masonry construction, and where digging for sewers would not be likely to injure it. Elaborate provision was made for drainage, ventilation, and illumination, the light being furnished by arc and incandescent lamps. It was early decided that the two easterly tracks of the four-track subway should be for north bound cars and should have island platforms between them and that the westerly tracks should be for south bound cars, and should also have island platforms between them. The platforms have been built as near the surface of the street as practicable in order that the stairways might be as short as possible. The subway is entered by handsome little stations at the street level, giving independent access to each track. At the Public Garden, by exception, one enters the subway on the street level, the cars entering and leaving the tunnel through an open avenue which leads, by a general slope 318 feet long, from the surface of the ground to the subway portal, which is inclosed by an iron fence with granite walls and concrete masonry.

Steam railway crossings.—The subject of bridge and tunnel construction is allied in some degree with that of safety provisions for steam railway crossings. The schedule of inquiry embodied a request for information as to the number of such crossings protected and of such crossings unprotected. From the statistics shown in Table 94 it appears that there were 4,481 steam railway crossings encountered along the tracks of street railway systems. Of these, 2,514, or 56 per cent, were protected, and 1,967, or 44 per cent, were unprotected. The protection referred to varies in character; in some instances it includes the depressing or raising of the tracks. Where a crossing is made by an overhead track, the street railway company naturally employs a bridge or viaduct, and such construction would be included in the returns already discussed. On the other hand, where the street railway depresses its tracks, the steam railway, of course, crosses over the street railway on its own bridge. These matters are generally a subject of adjustment between the different interests, although in many cases the dispute over right of way has been attended by litigation and even by physical conflict and the tearing up of tracks. Crossings are also said to be protected when provision is made for giving warning by a flagman or an alarm bell, but provision of this nature has but too often been found inadequate. Serious accidents and fatal collisions, due to the failure of such protection, are fresh within the memory of the public. Within recent years, work of a costly and elaborate character has been undertaken in such cities as Chicago and New York to obviate the need of having the street railway and the steam railway lines cross at grade. The New York Central and Hudson River Railroad Company, whose lines lead immediately into Manhattan Island, were crossed on the level by street railways at numerous points, until the completion of the viaduct and of the sunken way which now extends for miles out into Westchester county. The reform in this direction of late years has been quite considerable in all large American cities, and has been prosecuted at an enormous expense, so that, of the steam railway crossings now reported as unprotected, a large proportion are to be found in rural districts. Strictly speaking, they seem to be most numerous along the fast interurban roads which necessarily cross main lines of steam railway in outlying regions with such infrequency as not to necessitate any elaborate measures of precaution, but permitting both the steam railway company and the interurban street railway company to depend upon the intelligence of the motorman and conductor, governed by the rigid rules laid down for their guidance as to behavior at such intersecting points. The general practice with all street railways is to cut the overhead circuit at the railroad, so as to avoid any obstruction there, and to carry the street railway cars across by their momentum. The American Street Railway Association has in recent years endeavored to establish a national code of standard rules for the men employed. The development of interurban signaling may be gathered from the fact that for the year 1902–3 the special committee on this subject presented a section of about 2,000 words containing suggested rules, whereas before that time no special rules had been suggested, except a few on the subject of semaphores and color signals. While these rules do not necessarily or even largely relate to steam railway crossings, they do embody a variety of careful and explicit instructions, the observance of which should in every case be sufficient to prevent any accident. As a general thing, the methods of signaling advocated and formulated by the association committee follow closely the methods employed on the steam railways, and the rules, as reported, have proved satisfactory to the state railroad commissioners to whom they have been submitted.

CHAPTER III.

CARS AND MISCELLANEOUS EQUIPMENT.

I.

STREET RAILWAY CARS.

General statistics.—The statistics of cars and miscellaneous equipment connected with cars are to be found in Table 95. There were 66,784 cars of all classes reported to the Bureau of the Census, or almost exactly 3 cars per mile of track. Of this number, 60,290 were passenger cars and 6,494 were cars used for express, company work, or other purposes. Of the passenger cars, 32,658 were closed and 24,259 open, the latter style being reported very generally by all the companies, both North and South. One hundred and five companies reported 3,134 combination closed and open cars, of which 1,203, or 38.4 per cent, were used by 22 companies in California alone, the state in which the combination car had its beginning. Subsequent portions of this chapter deal with the evolution and typical features of this type of car, which bids fair to become a prevalent, if not a preponderant, style in the near future. Combination passenger and express cars were reported by 99 companies, the number used being 239. Cars used for more than one service have been enumerated but once. Cars carrying express, mail, etc., in addition to passengers have been classified as primarily passenger cars, the other service being more or less incidental to the regular functions of the car.

The use of special express, freight, and mail cars was reported by 205 companies. The largest number of these cars was shown by an interurban freight line, the St. Louis and Belleville (Ill.) Electric Railway Company, operating in the vicinity of St. Louis, which, with 213 cars and 2 electric locomotives, reported 209 cars for express, freight, and mail purposes. These cars, however, were without electric equipment, so that this road could hardly be taken as typical of the manner in which a freight service has been built up in connection with a regular passenger system. The 1,727 snowplows reported do not include snowplow attachments of a removable character, but are cars regularly and exclusively used for clearing the track. This is true also of 793 sweeper cars, while cars employed as both sweepers and snowplows are counted but once in the class in which the larger part of their work would place them.

Out of 66,784 cars of all classes reported, 50,699 cars were provided with electric equipment. The roads operated entirely, or in part, by electricity reported a total of 65,949 cars of all classes, the number provided with electric equipment being 76.9 per cent of the total.

Distribution of cars.—The largest number of cars of all classes was reported by the state of New York, with 14,040, or slightly more than 20 per cent of the total. Of this number, a little more than one-half was reported by three systems: The Interurban, of New York city, 3,063; Brooklyn Rapid Transit (surface and elevated), 3,504, exclusive of 121 steam locomotives; and the Manhattan (elevated), 1,331, exclusive of 292 steam locomotives. The figures of the Interurban, in New York city, should include additional cars of the other systems operating under the same management, which are reported separately. The total number of cars reported in the state of Massachusetts was 8,310, of which 3,612 were owned by the Boston Elevated Railway Company. This is the largest number reported by a single company, and includes cars operated on surface, elevated, and underground tracks. Illinois is third, with 7,788, of which about two-thirds were reported from Chicago. The other important states are as follows: Pennsylvania, 7,058 cars, of which 3,283 were returned by the Union Traction Company, of Philadelphia, and 1,252 by the Pittsburg Railways Company, of Pittsburg; Ohio, 4,395 cars, the largest number, 1,105, being reported by the Cincinnati Traction Company; Missouri, 2,484 cars, of which about half were to be found in and around St. Louis, the St. Louis Transit system alone reporting 1,179; New Jersey, 2,165 cars, largely engaged in New York suburban business on the New Jersey side of the Hudson river; California, 2,056 cars, of which 1,005 were reported by the United Railroads of San Francisco; Michigan, 1,757 cars, of which 920, or more than one-half, were the property of the Detroit United Railway Company; Indiana, 1,146 cars, a large proportion of which were in service in and around Indianapolis; and Minnesota, 1,083 cars, nearly all being operated on the Minneapolis-St. Paul system.

Express, freight, and mail cars.—Two hundred and five companies reported a total of 1,114 cars devoted solely to express, freight, or mail business. The largest number reported by any one company was that of the Belleville (Ill.) system, which, as already noted, is a freight road rather than a street railway within the common acceptation of the term, and which had one or two electric locomotives to haul its ordinary freight cars. The freight and express business is largely confined to interurban roads, but mail street cars are employed in a number of cities. The states showing the largest number of cars of this class are New York with 181 and Massachusetts with 94.

Work and miscellaneous cars.—The distribution of work and miscellaneous cars does not call for much comment, as practically every independent street railway system requires such an equipment for its ordinary maintenance and operation, and the larger the system the greater, necessarily, will be the number of such cars. The number of these cars owned by any road depends upon the amount of repair work done, the length of track covered, and the amount of construction work performed by the company's own force and equipment. The states showing the largest number of cars in this class are New York with 452 and Pennsylvania with 285.

Snowplows and sweepers.—For the United States, as a whole, 1,727 snowplows were reported. Out of the number thus given, 740, or nearly one-half, were reported for the state of Massachusetts, and of these 534 were owned by the three systems of Boston and its suburbs. New York state reported 241, of which 70 were owned by the two leading systems in New York city and Brooklyn. Sweepers, reported separately in the table, are sometimes employed for the same purpose as snowplows. The snowplow is equipped with a share, usually so adjusted that it is free to conform to the unevenness of the rails, and is often provided with an indicator showing the exact height of the share from the rail. The plow pushes the snow by sheer force to the side. The sweeper, on the other hand, is equipped with rotary brooms or brushes, the brooms being set at an angle to the shaft and also at an angle to the car track, so that they throw the snow clear of the rails rather than ahead. The brooms can usually be raised or lowered by levers, and some of them are double-enders—that is, with a broom or sweeper at each end of the car. Both snowplows and sweepers are necessarily heavily motored and are ordinarily run over the tracks at high speed. While sometimes used for snow removal, the sweeper is commonly employed for street cleaning purposes, and in some cases has sprinklers attached, so that the street can be sprinkled ahead of the sweeper brooms, or after it, as desired. There were 793 sweepers reported for the United States, of which New York state reported 188 and Pennsylvania 155.

It is obvious that an additional burden is thrown upon roads situated in the snow belt, which are compelled throughout the winter months to operate constantly one or both of these forms of apparatus for keeping the tracks clear. In like manner third-rail roads in the more northerly latitudes often have rail trouble to contend with, in addition to keeping their tracks clear of snow, especially if such roads are on the surface. This trouble is due to the necessity of keeping the head of the third rail clear of ice and sleet, which forms a partial insulation and prevents the delivery of current to the contact shoes. This difficulty has been met generally, not by separate cars for clearing away the ice or sleet, but by placing sleet cutters or grinders under the sills of the traveling cars, so as to clear the way for the shoes just behind. It is of course easy to equip the plow or sweeper on such roads with these additional devices for keeping the whole track clear.

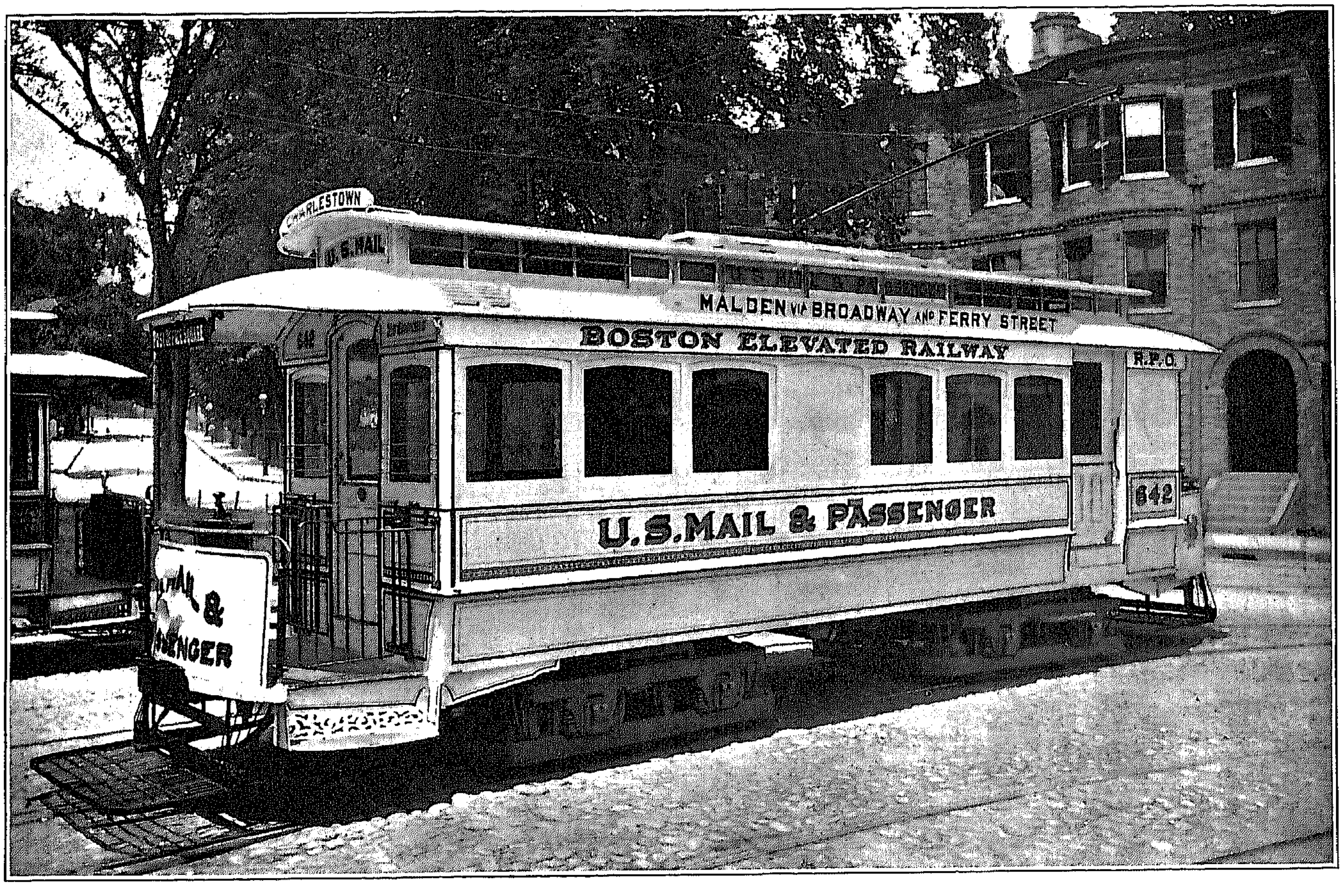
No figures were obtained separately as to the expense of snow removal, but in a long and hard winter the addition to operating expenses due to this cause is quite marked. The report of the railroad commissioners for New York state for 1902 includes some very interesting figures on the subject. The Metropolitan Street Railway Company, of New York city, reported for that year, the winter of which was a moderate one, an expenditure of $43,826 for the removal of ice and snow. The Brooklyn Heights system reported $44,014 for this purpose, in addition to $13,449 for cleaning and sanding the track. The Rochester Electric system reported for the same two items, $10,388; the Buffalo Street Railways, $6,691; and the International Railway Company, operating in the Niagara region, reported for the removal of ice and snow alone, $15,656. The Hudson Valley, operating through the northern portion of the state, reported $3,392 for the removal of ice and snow and cleaning track. At Schenectady the outlay reported by the company was $3,394 for removal of snow and ice and $2,554 for cleaning and sanding track. Such figures as these indicate the heavy expense incurred in dealing with the weather conditions in the Northern states.

II.

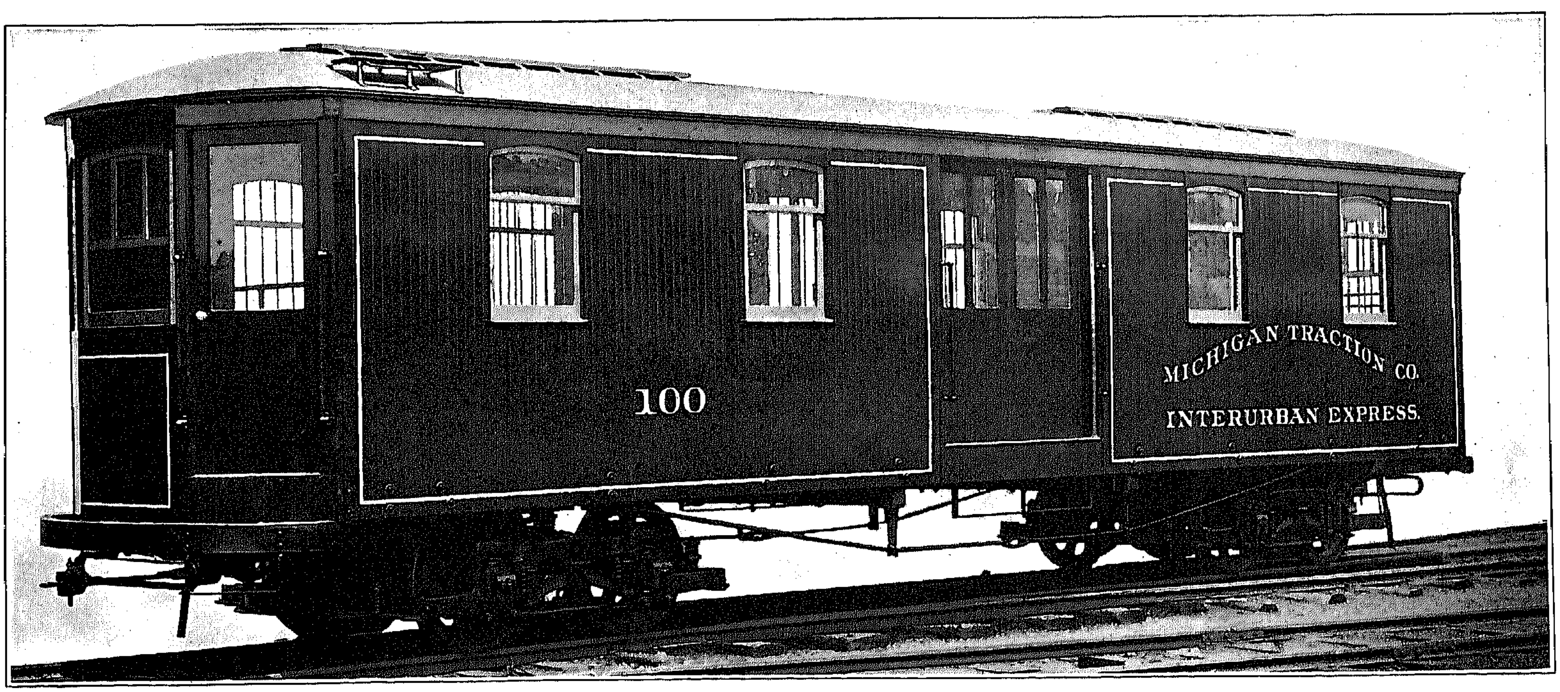
PASSENGER CARS.

Early styles.—Few classes of street railway equipment have undergone greater changes than have cars and trucks. The very first cars used were nothing but stagecoach bodies running on tracks, and for many years, in street railway as in steam railway coaches, could be traced the signs of their origin in the curves of the old stagecoach body.

There was soon manifested a tendency, however, to give to street cars a square or box-like form corresponding to that of the steam railway cars about the middle of the last century. The pattern of the old universal 16-foot horse car, similar in design to that of the stagecoach, persisted, however, up to the time when cable traction was introduced, and even to-day some of the old-fashioned "bobtail" cars still exist. These



TROLLEY MAIL AND PASSENGER CAR, BOSTON, MASSACHUSETTS.



INTERURBAN TROLLEY EXPRESS CAR IN MICHIGAN.

early cars were of very light construction, the body being entirely of wood, lightly veneered, the wheels of iron, and the cars themselves almost as springless as a country buckboard. An example of this form of car is shown opposite page 160, the cut being made from a photograph secured by one of the special agents of the Bureau of the Census while collecting data for this report in Alabama.

The cable, however, compelled street car builders and street railway managers to face the new problems of weights and strains, and one of the first results was the abandonment of the bobtail car, and the construction of vehicles of larger carrying capacity. Mr. John Stephenson, the famous American street car builder, has stated that in 1882, out of 428 roads then in operation, 279 were equipped with small bobtail cars and only 149 had large cars requiring a conductor as well as a driver. At that time two-thirds of the orders on his books were for the small cars. He stated that one of the main reasons for their use had been that three of the small cars could be used successfully when two large cars had proved a failure, the three giving a somewhat quicker schedule. Another reason was that the short bobtail car avoided strain on the horses. Two horses seldom start together, but in the case of a bobtail car one horse could easily do the work with better footing on the track. The objection to bobtail cars that passengers found difficulty in pushing their way to the front of the car to deposit fares in the box under the eye of the driver was, he thought, overcome by the device, then new, known as a "fare conveyer." This consisted of metal tubes passing around the interior of the car, and sloping from the rear down to the front in such a manner that a coin deposited in the tube, acted upon by gravity, would roll down into the fare box. Such conditions were, of course, improved by the introduction of the conductor on the horse lines, and largely disappeared when the cable car was introduced.

The labor of animals under the old horse car system was very severe, and their lifetime in the service was brief. The most severe strain was in the frequent stopping and starting of cars, during which the horses wrenched themselves, slipped and fell, and were compelled every few hundred yards to pull a heavy load from its dead rest. In New York city full cars often made a dozen starts from dead rest within the distance of two city blocks. It was estimated at this time that this strain resulted in shortening the life and utility of horses in the service on the average from three to five years.

An element of risk and uncertainty in connection with the use of the horses was found in their liability to disease, which sometimes took an epidemic form, completely paralyzing large railway systems. The daily travel of a street car horse averaged only 10 miles with single cars and 15 with double cars. With one day in seven given to the horses for rest, a large number of relays were required, and hence huge stables became necessary. Many of these had to be placed in parts of the city where real estate was expensive. At the same time the presence of such an establishment tended to reduce the value of property in the vicinity on account of odors and other unsanitary conditions. In hot summer months large numbers of car horses died on the streets in harness, and at all times a large veterinary staff was maintained to keep the stock in condition for its duties. Moreover, the stables needed a large force of hostlers, shoers, and stablemen, as well as elaborate arrangements for the supply of feed and the removal of refuse.

It is not surprising that street railway managers were somewhat eager to break away from these conditions, but as late as 1890 there were nearly 15,000 horses engaged in hauling street cars in New York city alone. Allowing an average of 40 square feet to each horse, or a stall 9 by 4½ feet, these 15,000 horses occupied some 600,000 square feet of stall space in the stables. They were required to haul some 2,400 cars, an average of not less than 7 horses to each car, the number based on cars in actual use being somewhat larger.

As already noted, one of the first changes in the style of the street car was the adoption of the box form, with vertical and horizontal lines instead of the curves of the old stagecoach or the omnibus. The lower part of the sides of the omnibus were made concave in order to provide space for the large wheels, but the small wheels of the street cars could be put entirely under the body, so that the concave form was no longer necessary.

When the cable came in, requiring a car that would withstand the different strains and the heavier loads, the science of car building had to be studied again. Some idea of the changes necessary may be gained from the fact that even in one of the old-fashioned 16-foot cars as many as 1,300 pieces of wood were required. In the cable car, not only were heavier timbers needed for structural body work, but resort was made to iron and steel as a substitute for wood where a gain in strength would follow their employment. The adoption of electricity again made changes necessary in the car-building art, due to the fact that cars now carried their own self-propelling mechanism. In America neither the horse nor the cable developed for permanent use cars known as double-deckers, those in which the passengers may ride on the roof as well as within the car. In England the double deck car is almost universal. The outside seats permit of smoking, and are attractive for observation purposes. Women as well as men use them freely. In Paris, which is one of the very few cities on the continent of Europe where double deck cars are used, a lower fare is charged for outside seats. Possibly for climatic reasons the double deck car and the omnibus with outside seats have never been popular in the United States. There are, however, some sections of the country, such as the South and California, where they could be easily adopted if the public desired. Some of the horse and automobile stages in New York have had outside seats, but the street cars have always been single deckers. Double deck cars have been tried in Washington, Pittsburg, Boston, and some other eastern cities, and also in Oakland and San Diego, Cal. It is obvious that in making provision for the upper deck the style and type of the construction must be greatly modified. In dealing with American practice it will be understood that single deckers are always referred to.

Before proceeding to the subject of electric street cars, it may be pointed out that the cable system introduced the trailer, a type of car which was previously unknown. With horses one car was all that the team could pull, but with cables, so long as the gripping mechanism under the grip car was strong enough to hold, and so long as there was power enough applied to the traveling cable in the conduit by the power plant, there was no reason why a train of cars could not be hauled. In this way the cable system developed both the grip car and the trail car. Toward the close of the cable era it was not an uncommon thing to see a grip car hauling three or four trailers, constituting a regular train like those running on steam railway tracks. The grip car constituted the locomotive, but being without the faculty of reversing its motion and direction in case of emergency, it could not stop its heavy train quickly, and serious collisions and accidents took place.

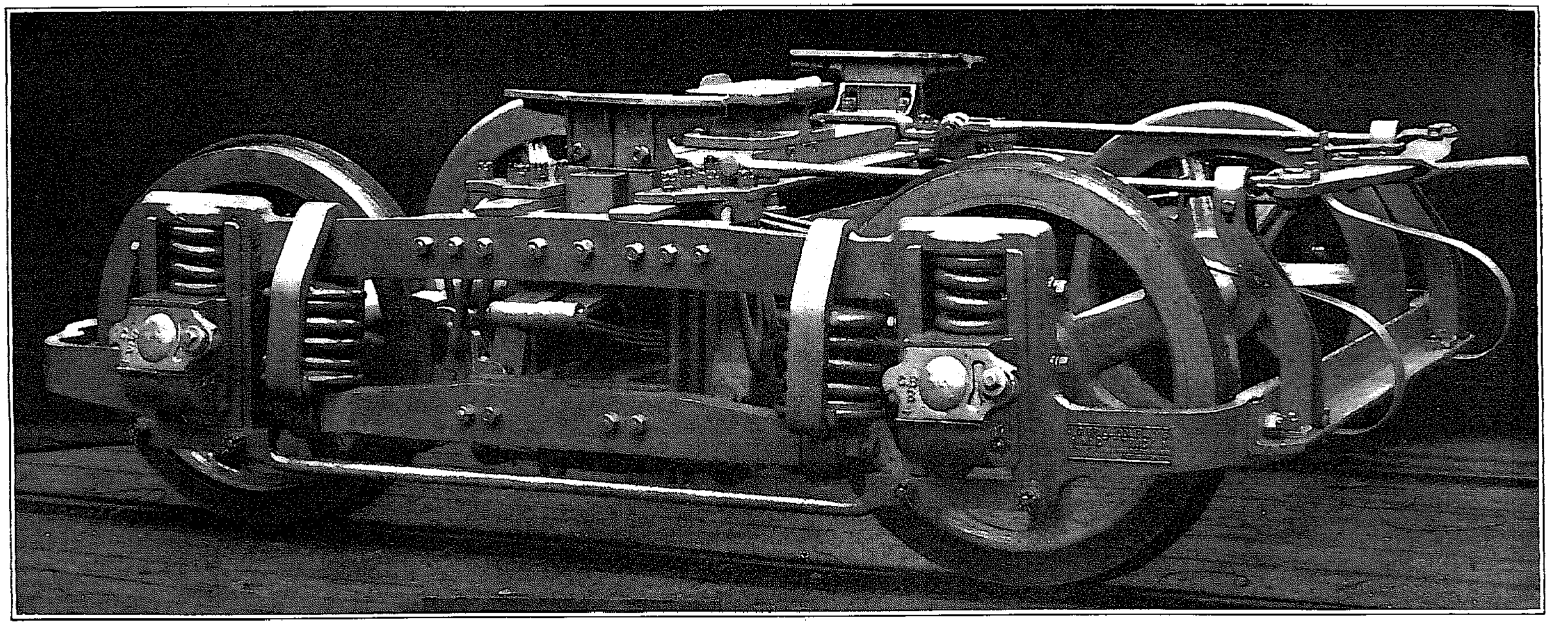
As with horse cars, the first cable cars, whether grip or trailer, were closed. The open cars for summer use came later. A further modification was found in the combination car, a part of which is open and the other part closed. A later improvement was the addition of what has become known as the vestibule, an inclosure occupying the front and rear platforms and affording shelter and protection to the drivers. One other fact to be noted in cable car development was the use of 8-wheel as well as the 4-wheel cars. The use of double the number of wheels and trucks made the car much more comfortable. But the running gear of a 4-wheel horse or trail car could hardly be regarded as a truck in the sense in which that term is applied to the appliances upon which the body of the mechanically propelled cars is mounted. The self-contained motor truck may be said to have come into use with the advent of electric traction.

First electric cars.—The earlier forms of electric car bodies and trucks adopted in the United States must be regarded as no less experimental than were the motors and other features of electric traction upon which the success of the art depended two decades ago. Hardly a car existed at that time built specifically for electrical work, an old horse car, or possibly a cable car, being usually put into shape to receive the electrical apparatus. There was no agreement as to whether the motor should be put under the car or on the front platform, or in the middle of the floor of the car itself, and the arrangements for the overhead trolley connections were equally indefinite. Nevertheless, it was out of the early and confused attempts at construction that the present forms appeared.

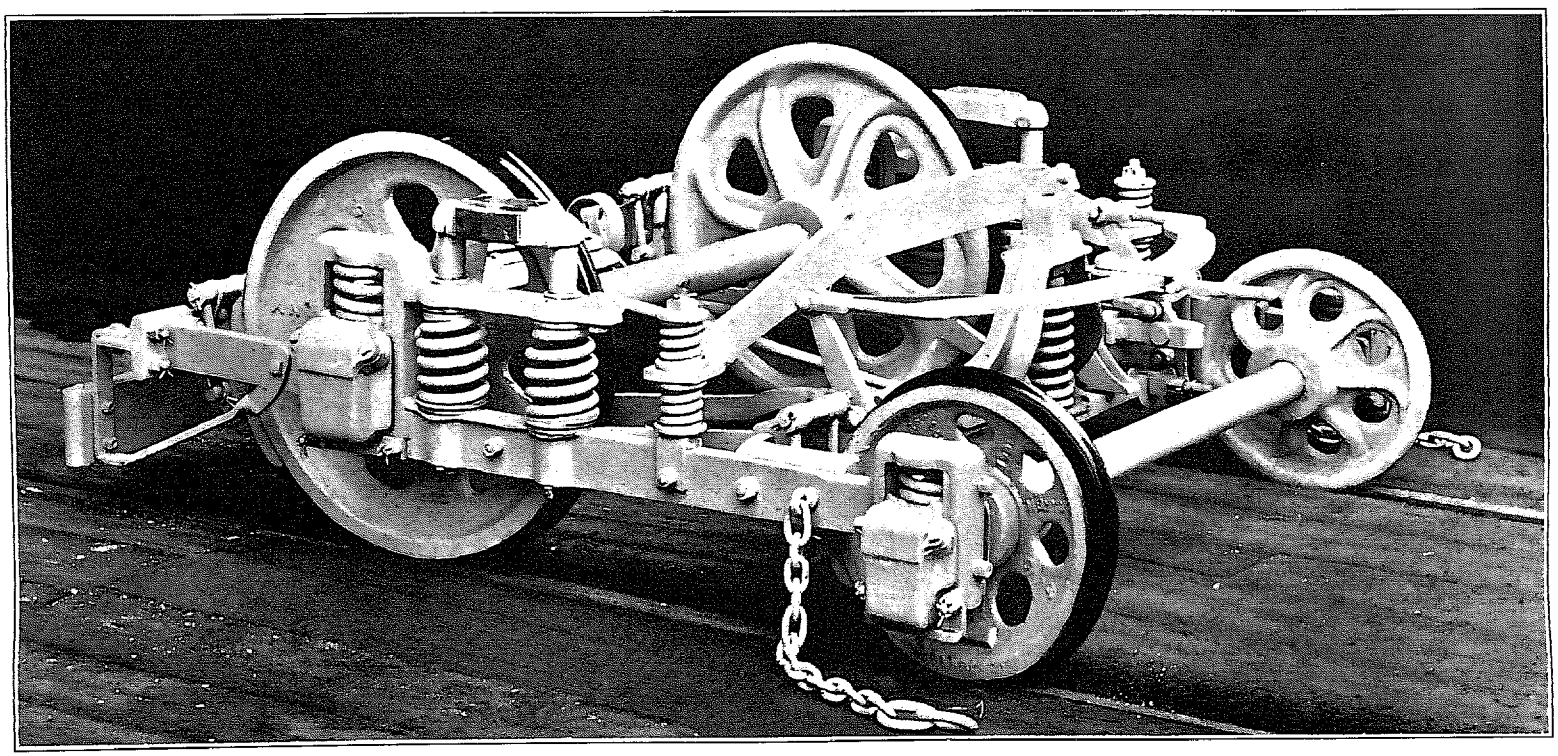
Along with the improvements in the forms of motors and methods of motor gearing, as well as in the overhead appliances, went experiments and improvements in the car bodies and car trucks. In the beginning there was the primitive single truck, and 5 or 7 ton cars, and now there are the long double-truck cars, equipped with 4 motors each, and weighing 20 tons. For some time the single motor trucks with 16-foot, 18-foot, and 20-foot cars persisted, but double-truck cars, from 30 to 40 feet in length, were later generally adopted as a standard in cities of any considerable size. The separation of trucks from the car body also brought into existence a new class of manufacturers, devoting their energies particularly to truck construction. The truck itself began to take on the girder form; some of the manufacturers built a special type of pressed steel frame, and others introduced cantalever principle.

It was soon found that the horizontal and vertical stresses in an electric car were very different in ratio and intensity from those experienced in a steam locomotive. The locomotive hauls a heavy load, its own propulsion being merely incidental, while the electric car has to propel itself with a heavy load on board, and only occasionally does it have a light trailer attached. Hence, the locomotive has been given a high degree of lateral as well as vertical stiffness. According to Mr. Edgar Peckham, whose name is closely identified with the subject, riveted cantalever truck frames were furnished to the Brooklyn City Railway, of Brooklyn, N. Y., in 1892, for use under 20-foot closed cars having an over all length of 28 feet. These were the first electric cars built of that length, and it was questioned whether a single truck with a 7-foot wheel base could support such a car body. As the result of the trial with the cantalever truck at that time, over 1,200 were supplied to the road in 1893, 1894, and 1895. These remained in use for several years afterwards without loosening their rivets, and thus demonstrated the ability of the cantalever truck to carry its load successfully under severe conditions.

The other general type of truck is that known as the Brill solid or wrought forge frame, which embodies the application of an opposite principle. This has also enjoyed a large amount of patronage from street railway companies. At the present time the practice is still more or less divergent in this respect, some makers forging the side frames of the truck and welding the whole together into one piece, while others adhere to the bridge-and-truss plan and build up what may be called an assembled truck. The disposition of springs under the truck to support the weight of the car varies greatly among different builders, but the results aimed at are



TRUCK FOR HEAVY DOUBLE TRUCK TROLLEY CAR



the same in every case, namely, smooth running; rigidity of frame that will withstand the stress tending to throw the axles out of alignment when the car is rounding curves; ability to resist longitudinal strains due to incidental changes in the contour of track; and the reduction of the uncushioned weight on the wheels.

Modern electric cars.—In the construction of modern street car bodies the larger proportion of the material consists of lumber, certain woods being favored and generally used. In the beginning a great many different kinds of wood were used, some cars being elaborately decorated, but at the present time plain trim is the rule, even in parlor and private cars. The kinds of wood in use for structural purposes, such as bottoms, platforms, sides, and ends, are white oak, white ash, yellow pine, poplar, white pine, rock elm, and hickory, or woods which answer to these general names; while for finishing purposes cherry, maple, and white ash or poplar, white oak, bird's-eye maple, red birch, and mahogany are employed. The oak, ash, and hard pine come chiefly from the southern states of Tennessee, Kentucky, Mississippi, Alabama, Georgia, and Florida; the birch, cherry, and hard maple from more northern states and Canada, and the mahogany from Central America and Mexico.

Glass is also an important material in street car building, consisting usually of window glass and plate glass styles, but including also some opalescent glass and colored glass for ornamentation and for signals. Plate glass has come into very general use of late years, not only because it is stronger than ordinary window glass, but because it adds very much to the appearance of the car and to its attractiveness.

The upholstering of cars varies greatly. At one time street cars were usually upholstered with woolen material, but this practice is not now so general, objections being raised to it on sanitary grounds. The backs and seats are now of plain wood, rattan, leather and its various substitutes, or light carpet, which can be readily removed. The curtains are made of various materials, some being prepared especially for the purpose, but not differing greatly from those employed on steam railroads. Wooden sliding blinds or shutters, once popular, are not now in use to any extent. In early days of street railroading it was not unusual in winter to find the floors covered with straw for purposes of warmth, a practice which, however, has long been abandoned on account of the introduction of various artificial methods of car heating. The floors are now often covered with frames of wooden slats, which can be easily removed for cleaning purposes. The car builder or street railway company to-day usually purchases a great many of these materials in the open market already made up. This is also true to a large extent of the various metal parts, of iron, steel, brass, etc., needed for the car trimmings and finishings.

Such details as car lighting, heating, etc., are discussed in other sections of this report. Descriptions follow as to typical city cars. Special attention is also given elsewhere to interurban roads. The standard closed car in Baltimore measures 28 feet in length over end panels and 38 feet over crown pieces, has a width of 7 feet 10 inches, and weighs without passengers or motors 21,760 pounds. It is fitted with portable vestibules, and the end door is set slightly to the side nearest the step, so as to make entrance easy. The platforms are 5 feet long. The seats are arranged longitudinally, a practice generally followed with closed cars in cities, although a great many have cross benches. The standard open car in Baltimore is 38 feet 9 inches over crown pieces and has 12 benches running across the car. It is fitted with a 9-inch running board on each side, with folding steps of iron, the height of the running board from the head of the rail being 18½ inches. Complaint has been made frequently of the height of the running board or step, but it is unavoidable because of the space required under the car for the larger and heavier motors now in use. An engraving is here shown of a large open car of the standard type employed in Buffalo, New York.

The standard closed car in Boston has a 25-foot body with platforms about 4 feet long, the step being 16 inches from the rail. The weight of these cars complete is 24,660 pounds. They are mounted on maximum traction trucks or center-swivel double trucks. The standard summer car is a 12-bench open car of about the same length, on double trucks. Some 9-bench open cars on single trucks are also in use.

In Chicago, Ill., a type of semiconvertible car has been introduced which is one of the heaviest and longest known. This car is 48 feet 2 inches in length and weighs 48,000 pounds. Each platform is 6 feet 5 inches long. The width of the car body is 8 feet 8 inches, which provides for a center aisle between the cross seats. The height of the step from the rail is 16 inches, and from the step to the platform, 12 inches. The window sash lowers into the space between the car sheathing and the inner wall, and a low window sill provides a large window space which adds to the comfort of the car in the summer. The opening at each end of the car has sliding doors, and is the full width of the aisle when both doors are open, the doors, however, being independent of each other, so that only one need be opened at a time. At transfer points and termini both doors can be opened and the car quickly emptied by allowing the passengers to leave two abreast.

In Milwaukee, Wis., a standard car adopted some seven years ago is still in use, the only change in its original style being that four motors are now employed instead of two. The car is of the semiconvertible type, with cross benches, accommodating 44 passengers. It rests on center-swivel trucks equipped with 4 motors and 33-inch wheels, and has one step between the rail and the platform and a rise from the platform to the car. In this last respect the car was an innovation, scarcely a car of this type and size having previously been known which possessed so low a platform and in which only one step was needed between the platform and the ground. The latest type of city car built in Milwaukee upon these lines is 41 feet long over the bumpers. Double side sills allow the sash to be lowered between them, and the window sills are made a little lower than usual, so that the car is practically an open one when the windows are lowered in summer. Owing to the narrowness of the bridges that the cars have to cross, protective wire netting is placed at each window opening in summer.

The combination type of car, half of which is closed and half open, is said to have had its origin on the Pacific coast, where it is still in use. The earlier types of combination cars on the United Railroads of San Francisco had longitudinal seats in the open section, facing outward, a feature which is quite unusual except in observation cars, such as may be found along what are called scenic routes. Such cars are found, for example, in the Niagara gorge, with seats facing toward the water. The newer cars in San Francisco have cross seats in the open parts, with center aisles, the closed part, occupying the middle of the car, having side seats, and being entered from either end. The motorman or brakeman is stationed in the center aisle of the front open portion. The newer cars are 39½ feet over all, have a seating capacity of 44, and weigh 33,500 pounds.

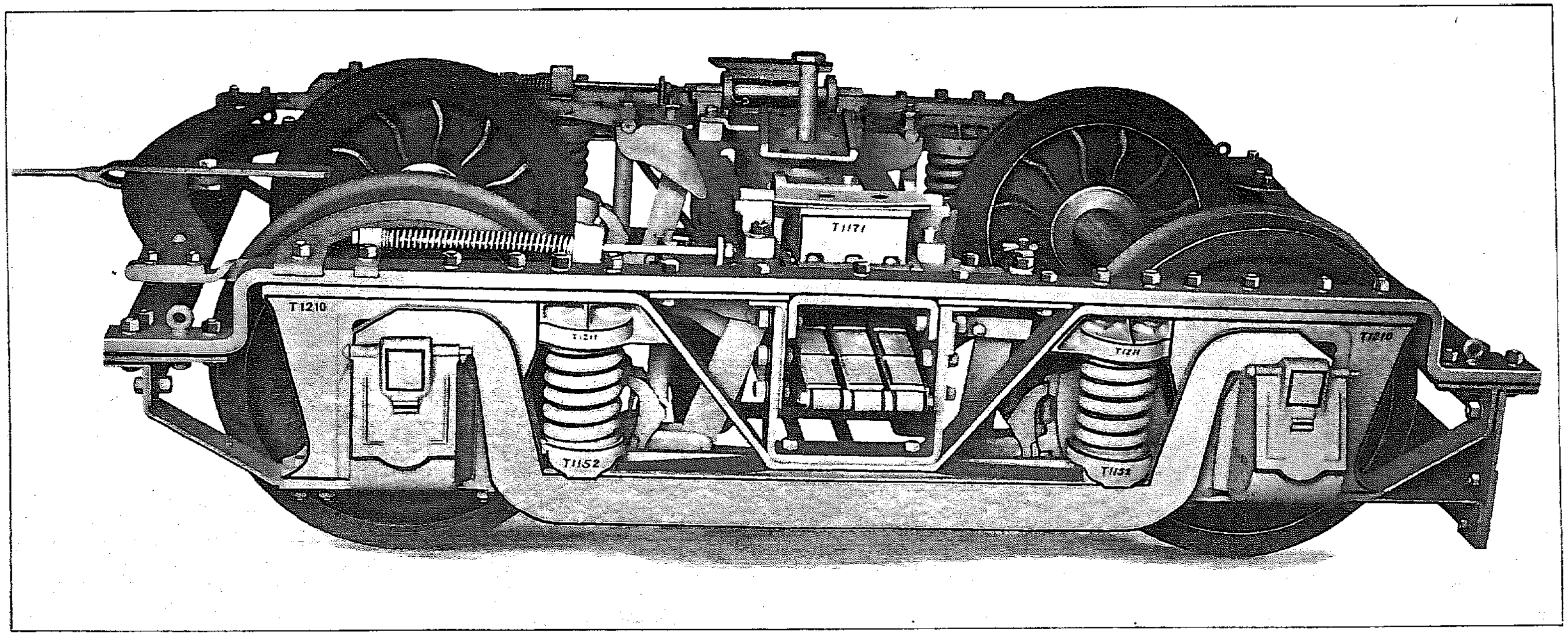
In St. Louis, Mo., the semiconvertible car was first tried on a large scale, and almost all the street railway lines were equipped with this type. The latest cars ordered for St. Louis, to handle the World's Fair traffic, are of the semiconvertible type, suitable for use the year round. They are 44 feet 8 inches over all, with a body 33 feet 4 inches, mounted on center-swivel short-wheel-base trucks, carrying two motors on each truck. They are box shaped, without curves, being 9 feet in width both at the sill and at the belt rail. Channel irons serve as side sills and form the principal part of the car bottom. The platforms are of unequal size, the cars not being double-enders in the ordinary sense of the word. The front platform, 3½ feet long, is for the motorman, and for entrance and exit to the car, but not for passengers. The rear platform is 7 feet long and in three divisions, separated by hand rails. The division next to the door is intended to be kept clear for the entrance and exit of passengers, and the other two are for passengers, the hand rail furnishing a support to those standing on the platform, very much as the car straps do to those standing up inside the car. There is an opening in the railing at one point providing a standing place for the conductor. This is a modification of what is known as the Detroit platform referred to under the description of the Detroit cars. The seating capacity of these cars is 50 passengers. Another feature in St. Louis has been the introduction of a summer car which is practically without a roof. It has simply an awning as a protection against the weather, but this awning is usually kept rolled up so as to offer no obstruction to the free circulation of air. This car seats 96 persons, and in the warm, sultry evenings enjoys a large and grateful patronage.

In Philadelphia, Pa., the car last adopted as a standard is of the semiconvertible type, 38 feet over all, with 28-foot body, seating 40 passengers, and weighing, without load, 32,000 pounds. The body is so low that only one 13-inch step is needed to reach the platform, with an 8-inch rise from the platform to the car floor. Philadelphia adhered for a long time to the ordinary closed type of car with longitudinal seats, but the last 600 cars have been built with cross seats.

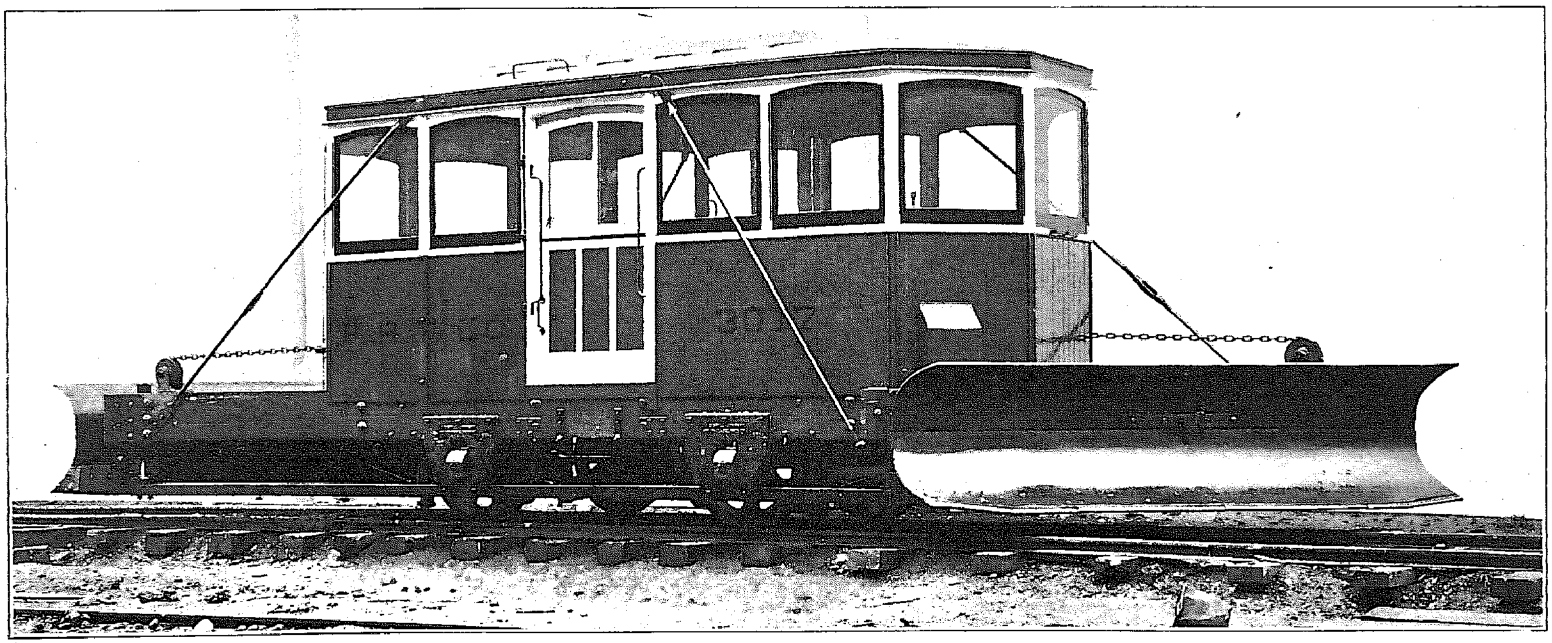
In Pittsburg, Pa., there are three types of cars in use, a single-truck open car, a single-truck closed car, and a double-truck closed car. The company uses trailers to some extent, with open cars, but is unable to use double-truck open cars on account of the narrowness of the streets. The latest double-truck closed cars are 42 feet 8 inches over all, with 30-foot bodies not less than 8 feet 6 inches wide at the sills, with straight sides and equipped with side seats. The single-truck closed cars have an over all length of 30 feet, being equipped with side seats and are somewhat narrower than the double-truck cars. The single-truck open cars are 24 feet 3 inches over all, 7 feet 10 inches wide, and fitted with 22 cross benches.

In Indianapolis, Ind., because of the heavy summer traffic, the open car is used to such an extent that it is a question whether it will ever be superseded by the semiconvertible type. A large number of these open cars are on single trucks, are 34 feet 5 inches in length over all, and have 12 benches seating 60 persons. The standard double-truck semiconvertible car employed on the system has a length over all of 45 feet and a body length of 32 feet, with a 6-foot rear platform. The front platform is occupied by a motorman's cab, which is so arranged that passengers can enter and leave the car by the front platform without interfering with the motorman. Part of the car seats are cross benches and part are longitudinal, and the seating capacity is 52 passengers. The car body is entirely straight in its lines, and the paneling is of sheet steel instead of wood which is the usual material.

In Detroit, Mich., a number of the open cars on single trucks have remained in use, but the later type is semiconvertible, with a center aisle and cross seats, the length of the car over all being 41 feet and the seating capacity 43 passengers. The front platform is 5 feet 6 inches, with a passenger entrance and a separate compartment, for the motorman, provided with a hot air heater. The rear platform is 6 feet 6 inches long, with provision for considerable standing room. It is what has become known as the Detroit type, the passenger



HEAVY TYPE, CANTILEVER TRUCK FOR TROLLEY CAR.



TYPE OF SNOWPLOW.

entrance being divided from the rear part of the platform, which limits the standing passengers by means of an iron or brass rail carried completely across the platform. This type of platform is in use in other cities, although sometimes modified, as in the St. Louis cars already mentioned.

The city of Denver, Colo., has a car which is quite different from that usually found either on the Pacific slope or in the East. It is 41 feet 6 inches over all, with a width of 8 feet 2 inches at the belt rail. It has no rear platform, as platforms are usually constructed, but has a platform or landing at the middle of the car, the entrance being at the side between two compartments. The front compartment is a closed one for nonsmokers, equipped with cross benches, and can be converted into an open car in summer by lowering the windows. The rear compartment is for more general use and has an open compartment for smokers. The side entrance and exit has the advantage that it can be more easily watched by the conductor, and that it can not be blocked by standing passengers, as can the platform. The seating capacity of the car is 48 passengers. There are two steps from the ground to the car, and it can be entered from the motorman's vestibule as well as from the side. It is well adapted to the variable climate of Denver.

A good illustration of the latest car construction in the South is to be seen at Atlanta, Ga., in the semiconvertible car of the Georgia Railway and Electric Company. On this car the lower side panels serve as sill plates, which, besides stiffening the side and giving longitudinal strength, provide a guard against injury to the car from collision with vehicles. It has straight sides, but the guard rail, and the division of the upper and lower panels give it a curved appearance, which is more graceful than that of the vertical box form. The sills are unusually low, bringing the top of the window sills only 24 inches above the bottom of the car. The windows are protected by three bar outer guards extending from corner post to corner post. The windows are stored in wood pockets in the manner often used in this type of car, and can be raised either full length or only part way. The car has a 4-wheel single truck base, and is 30 feet 8 inches long over crown pieces, and 7 feet 10½ inches wide over the sills.

The accompanying view of the interior of a semiconvertible car corresponds in general to the descriptions which have been given of cars of this type. There are, of course, numerous variations, embodying the ideas of manufacturers or street railway managers.

From the data which has been given, a general idea may be formed of the practice in the large cities of the United States with regard to the leading features of car construction. It will be seen that the semiconvertible car, adapting itself to city use for both summer and winter, during all weathers, has come into general use, although closed box cars with longitudinal seats for winter and open cars with cross benches for summer, are still the standard in New York city, Boston, Baltimore, Pittsburg, Cleveland, and Buffalo. Even in cities like New Orleans and Kansas City, where the milder climate might be expected to make open cars more popular, the semiconvertible car has been introduced. As a matter of fact, it has been the practice in New Orleans to use closed cars throughout the year, the severe thunderstorms which break over the city so frequently and so unexpectedly during the summer months preventing the abandonment of this type even during the warmest weather.

The semiconvertible car is in favor with the managers of street railways because it avoids investment in a double set of car bodies and the necessity of changing from summer to winter equipment, and it is also in favor with the public. Although it is not so open as the open type of car, it is a better protection in case of bad weather, and the speed of the car insures an adequate circulation of air. Again, with an ordinary open car with running board along the side, the passengers can not quickly discover a vacant seat or change easily from one bench to another. It is, in fact, almost impossible for a woman to do this except while the car is standing still. But with the semiconvertible car and its center aisle, a change can be easily and safely made from one bench to another. Furthermore, exit and entrance at the end of the car, directly under the eye of the conductor, can be made with more safety. It would appear, moreover, that passengers as a general thing prefer cross benches, giving a view outside, rather than the longitudinal benches which face inward. The semiconvertible cars, however, do not appear to be equal to the strain of abnormal traffic, such as comes upon roads at holiday seasons, particularly in the summer time, and for this reason many of the roads retain open cars for such traffic because they can be packed to a much greater degree.

The length of cars has been greatly increased, but limits in this respect are found in the difficulty of rounding curves of short radius, where the streets are narrow, and the interference with other vehicular traffic. It is probable that a car which has a length over all of more than 48 feet has reached the reasonable limits for city service, for with the increase of length goes an enormous increase in weight. Some eight or ten years ago the average dead weight per passenger with single truck electric motor cars averaged about 600 pounds. It has now reached 800 pounds on many of the semiconvertible and closed cars, and in the newer long cars of the Chicago City Railway Company the weight is over 900 pounds.

The American street railway manager or car builder has very little to learn from European methods. In England the double-deck car is largely in use and very few single-deck cars are to be seen. The same is true of Paris, where the inside seats are reserved for first-class passengers at a higher rate of fare than is charged the second-class passengers outside. The standard car for city service in Germany, Austria, Belgium, and in fact throughout nearly all of Europe, except in the city of Paris, is a single deck, single truck car, restricted in width and in over all dimensions, because of narrow streets and sharp curves, but with comparatively long platforms, to accord with the law which permits a certain limited number of passengers to stand on both platforms.

Double-truck cars with single decks are being introduced into certain cities with wide streets, as Berlin and Budapest. Open cars are used very little in any part of Europe, except in Italy, because of the uncertainty and dampness of the climate, the outside seats of the double deck cars, and the platform "places" of the single deck cars taking the place of the open car. The European practice of restricting the inside load of the car to the number of passengers who can be seated, is in part responsible for the large platform in the rear, already mentioned. Some of the platforms are 6 feet long, allowing standing room for 9 persons. Until quite recently the great majority of European cars have been of the 4-wheel type, 18 or 20 feet long in the body, with a seating capacity for 24 people, the shortness of the car giving the platforms an appearance of disproportion and clumsiness. In Germany the panels are sometimes made of sheet iron, but wood is largely in use. The lumber is to a considerable extent imported from America. The interior finish is, as a rule, not equal to that of the American street railway cars. Although Europe has its own car shops, and is now building more street railway cars than heretofore, there has been for half a century a steady demand from Europe, and other parts of the world, for American street cars and street railway trucks.

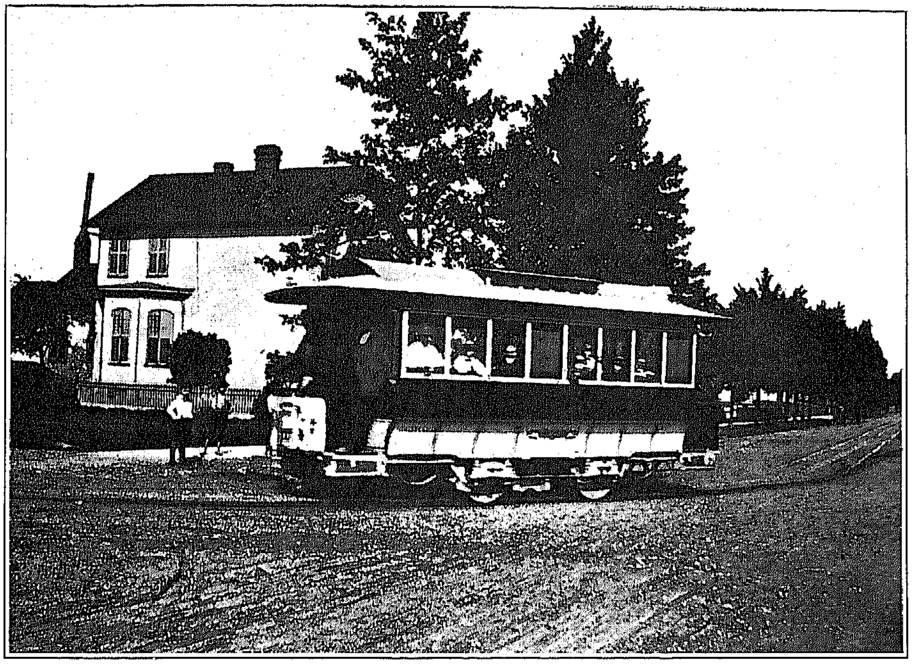
III.

ELEVATED RAILWAY CARS AND PRACTICE.

While the cars of all the elevated railway systems in the country are included in Table 95, it is not easy to determine the exact number that should be considered as exclusively designed and employed for elevated service. In Boston and Brooklyn, for example, elevated and surface railways are so connected as to make it difficult to segregate the figures accurately, as many of the cars are run on both surface and elevated tracks. In Brooklyn the situation is complicated by the fact that the Long Island Railroad connects with the Brooklyn Rapid Transit system soon after entering the city, so that a great many of the steam railway cars, operating over regular sections of road, become to all intents and purposes elevated cars, which can be handled either by steam or electricity. None of the statistics of the Long Island system, however, have been included in this report. This interdependence of the surface and elevated systems lessens the number of elevated cars proper. The Boston Elevated system, which reported a total of 3,612 cars, had, apparently, but a year later, only 156 elevated motor cars, the total number being very much the same as that for the census year 1902. On the other hand in the following year the Brooklyn Rapid Transit system, with practically the same number of cars as the Boston Elevated system, and with almost exactly the same number of cars as in 1902, reported 781 of the distinctly elevated type. The details are clearer when one comes to the statistics of the New York system, where the Manhattan Elevated reported a total of 1,290 passenger cars. In Illinois the city of Chicago comprises several elevated systems operating under separate managements, or at least under distinctive designations, and these reported as follows: Metropolitan West Side Elevated, 361 cars; South Side Elevated, 212; Northwestern Elevated, 203; and Lake Street Elevated, 141, making a total of 917 cars, of which all but 15 were passenger cars. The figures for the four great elevated systems of New York, Chicago, Boston, and Brooklyn would, therefore, appear to have, with fair approximation, a total of 3,144 cars of the specifically elevated type proper, but, as already pointed out, this would not by any means include the cars actually plying over elevated tracks.

The cars of the elevated street railways proper are necessarily different in many respects from those provided for surface traction, and this is true, although the methods of operation may be practically the same. There is obviously no necessity of employing an underrunning trolley conduit system with electric traction on an elevated structure, and the choice is left between the overhead trolley and the third rail. For standard elevated railway work in the United States the third rail has been universally adopted, although it may still be considered an open question whether in the long run resort may not be made in some instances to the overhead wire. The winter experience in such cities as Chicago and New York, when traffic has been interrupted by the formation of sleet on the third rail and the occasional accidents from third-rail contact and short circuits, have indicated some of the difficulties attending this method of operation.

The Manhattan Elevated road, operated by electricity, may be taken as an example of elevated railway operation and the cars of this system studied in detail. The company had at the end of 1902, 1,268 closed cars and 22 open cars, and was then adding more open cars for summer use. The practice of the Manhattan Company has been to operate these cars in 6-car trains, employing the multiple unit system. The motor cars have a length of body over the end plates of 47 feet 1 inch, and an extra width over the eaves of 8 feet 9.5 inches with a height of car from the top of the rail to the top of the dome of 12 feet 10.5 inches. The cars are electrically lighted and heated and have longitudinal benches with central cross benches. The motorman's



PRIMITIVE TYPE OF UNDER-CAR TROLLEY OR CONDUIT CONTACT, CLEVELAND, OHIO.

INTERIOR OF A "SEMICONVERTIBLE" CAR.

cab was designed by the company's engineer. When used as a cab it is cut off from the rest of the car by means of a glass door, and a roomy, box-like inclosure is thus formed in which the motorman can sit undisturbed and secure an unobstructed view of the track in front of him. When the compartment is not needed for motive purposes the motorman's seat is turned down, the door is folded back so as to protect the controlling apparatus, and a compartment is provided with seats for two passengers. A compartment is placed at both ends of the car so that either end can be occupied by the motorman.

The cars are built of wood, the underframe consisting of long-leaf yellow pine and white oak. Iron rods are used for strengthening the frame, and the roof of the car is supported by five principal car lines made up of 1.5-inch wrought iron bars, forged to the shape of the roof, and sandwiched between two white ash car lines bolted together. The motor and platform are supported by rolled open-hearth steel I-beams and channel beams. The trucks are of the swing bolster type with a 6-foot wheel base, the frame being rectangular and built up of angle iron. The bolsters are open-hearth steel plates and the pedestals for the journal boxes are of cast steel, with equalizing bars of steel 1 by 6 inches in section. The journal boxes are of malleable iron with brasses of phosphor-bronze lined with babbitt. The weight of a motor car with equipment complete is 51,800 pounds and the motor trucks complete with gears, but without motors, weigh 10,100 pounds. Each motor complete with gears weighs 4,420 pounds. The trailer trucks weigh 7,000 pounds each. Each motor car is equipped with two motors of 125 horsepower, both of which are mounted on the same truck, and all the motors of the train are manipulated together by means of the multiple unit control system, which is discussed on page 200 of the following section. The cars are lighted by 25 lamps of 16 candlepower each, set in the sides and ceiling, with 5 additional lamps at each end of the car for headlight, markers, and cab lights.

The cars are heated electrically, the heaters being in three circuits. Each heater has exactly similar coils and each circuit takes approximately 8 amperes of current, so that in very cold weather 24 amperes of current can be used to heat each car. The three circuits are numbered, and during the winter signals are posted at the terminals of the road under the direction of the superintendent telling the conductors what heating switches to throw in. These switches of the break-lever order are mounted in a sheet-iron box at one end of the car, the lighting switches being similarly mounted at the other end. The cars are equipped with the automatic air brake and the engineer's valve operated by a separate motor compressor under each car, which cuts in and compresses whenever the pressure in the main reservoir drops below a predetermined amount.

Open cars have been introduced on the Manhattan system since electricity was adopted, the annoyance from smoke and ashes making their employment impossible so long as steam was used. They are 47 feet 1 inch in length and 8 feet 6 inches wide over the side sills. All the seats, with the exception of the end one, have reversible backs, and all the doors of the car at the side are opened at once by a lever operating from the end platform. In this manner a more expeditious loading and somewhat quicker emptying of the cars is obtained, as contrasted with the slower results due to the use of one door only at each end of the car, or as compared even with the cars on the Brooklyn Bridge, where there are large doors also at the center of the car. The total weight of the open car is 29,400 pounds.

The question of fire on elevated street railway cars has always been a serious one, owing to the great difficulty experienced by passengers in leaving the cars in case of accident, and the difficulty in reaching the tracks with fire extinguishing apparatus. Serious efforts have recently been made to improve the fireproof qualities of the cars. On the Manhattan Elevated the bottoms of the cars have been covered with asbestos sheeting, and asbestos cloth tape 3 inches wide has been wrapped about the cables. The motor ends of the car have been incased in sheet iron and covered with asbestos. The New England Insurance Exchange and other insurance bodies have shown a tendency to insist that wires shall be incased in metal tubes in all electric cars, thus making the wiring uniform in method with house wiring. The Manhattan Elevated Company has adopted a type of car fuse which produces little noise or smoke. It consists of thin copper ribbon with a hole drilled in the center. All the copper that is burned away in case the fuse "blows" is practically vaporized. The good results obtained are due to the large radiating surface in comparison with the small amount of metal in the fuse.

The frequent and disastrous fires occurring recently in the underground railroad of Paris, due to short circuit on the cars and the subsequent creation of a large volume of suffocating smoke, have further directed attention to the importance of thoroughly fireproof and insulated cars on underground roads, of which the system in New York city, with the possible exception of the Boston subway, is the first example in America. The first cars adopted for the Rapid Transit Underground in New York city consist largely of wood, and every effort has been made to insure their fireproof qualities. The first floor is of maple, as that wood is slow to burn and does not carry flame; this rests on the sills. On top is a layer of one-eighth inch fine felting asbestos protection and then another floor of maple. All the timbers and the sides are covered one-fourth of an inch with asbestos board before any of the sheathing below the floor is laid. There are four sheets of quarter-inch steel above the motors, and the motor wires and control wires are all carried in asbestos conduits. On each cable are layers of asbestos insulation, and the sides of the cars from the floors to the windows are covered with copper sheets. The lighting and heating circuits are carried in asbestos conduits, and all the wooden frame is painted with fireproof paint. An all-steel car has also been developed by the company and has proved so satisfactory that it is stated all future cars put in the subway will be of this type. Although slightly heavier, they have the advantage of absolute noncombustibility.

IV.

MOTOR AND CONTROLLER EQUIPMENT.

Of the 65,949 street railway cars of all kinds reported by roads operating entirely or in part by electric power, 50,699, or 76.9 per cent, were provided with electrical equipment. The leading states reporting cars with this class of equipment were: New York, 10,222; Massachusetts, 7,801; Pennsylvania, 6,450; Illinois, 3,315; and Ohio, 3,188.

The variations in the proportion of the total number of cars reported in each state as provided with electrical equipment is due to the use on some roads of trailers, which have no equipment of their own.

Early motors.—At the time that motors began to be employed in street railway operation, much still remained to be done to perfect the motor itself. The idea of magnetic permeability and the measurements connected with it were very imperfectly grasped. Proper lamination of the armature cores to prevent heating was little understood or practiced, ventilation of the motor had not been solved, and iron or steel castings of the proper magnetic permeability were not obtainable.

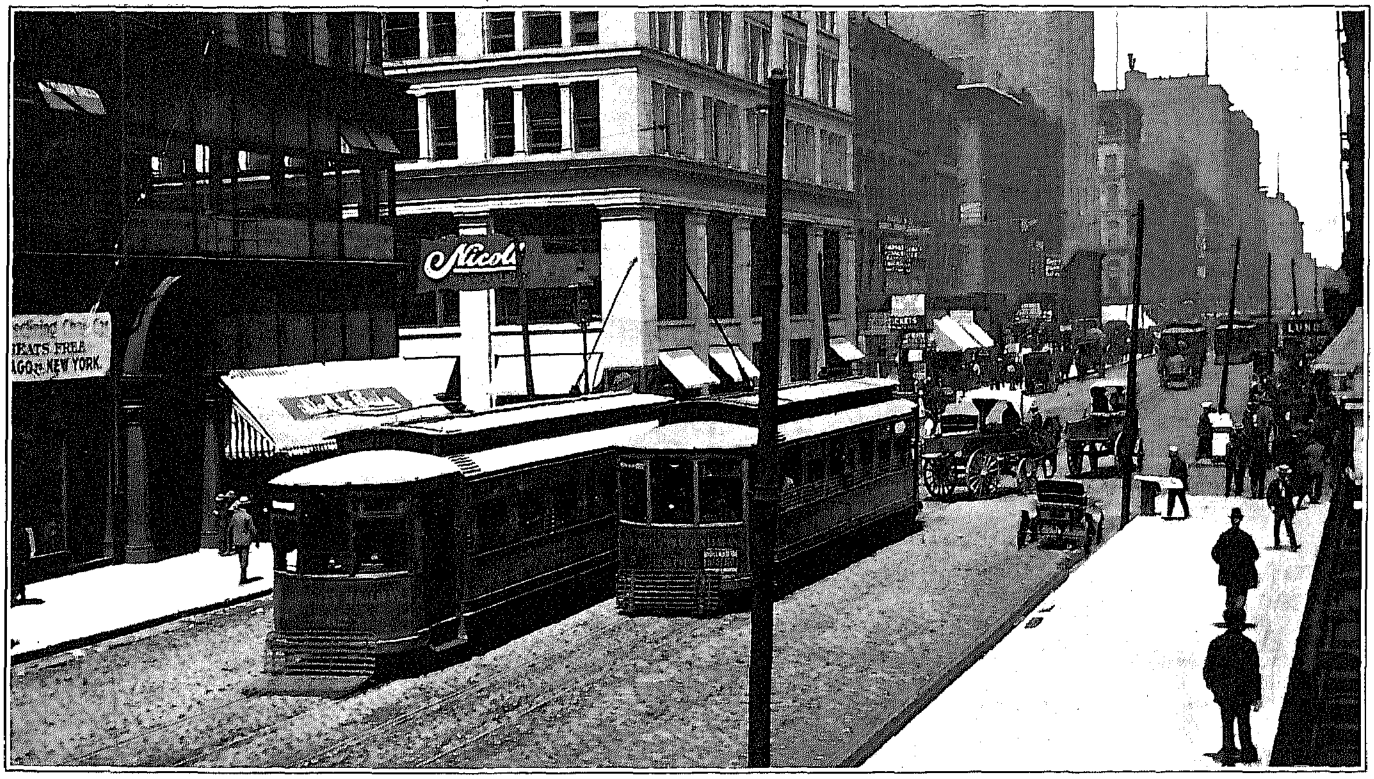
The matter of gearing required much thought and experiment. By improvements in design and construction, it was found possible to lessen the speed at which the armature of the motor ran, thus doing away with the necessity for one set of gearing between the armature and the car axle. One commutator on the motor was found to give trouble enough without resorting to the use of two, and it was found desirable to discard all methods of gearing except spur gearing, which could be inclosed in a gear case. In many of the earlier motor constructions other methods of driving were tried, including friction pulleys, ropes and belting, worm gearing, connecting rods, bevel gearing, and sprocket chains, but these have all been abandoned and spur gearing is now in general use.

The first machines of the prevalent modern type were those which were built ironclad, or so incased as to protect them from moisture and dirt, with single reduction spur gearing construction. These machines were generally from 20 to 25 horsepower. They were different from the motors used for other purposes, and from the early generating dynamos which were sometimes forced into service as motors on street railways. In some of the first attempts to operate street railways on the "series" system a form of arc light dynamo was employed, and in some of the first attempts to operate on what is known as the "multiple" or "parallel" system low-voltage dynamos used for incandescent lighting were tried. In neither case was the machine properly adapted to such work. The early employment of the double reduction gearing between the armature and the car axle was necessitated largely by this use of electric lighting dynamos with their bipolar form of field construction. With the introduction of the multipolar machine came a reduction in armature speed, which made it possible to dispense with one set of gears.

Among the early problems in connection with the equipment of cars with electric motors was the proper location of the motor in the car. It was shifted from the floor of the car to the front platform and then back to the car, and was finally placed underneath the car. Many earlier cars had the motor hung under the car body with one end suspended by springs and the other hung on the car axle. This was but a temporary stage in which the old horse cars were remodeled to meet the needs of electric traction. The car axle in such cases was lengthened to make room for the motor, and the floor of the car was strengthened to carry the additional weight imposed upon it. A serious objection to this plan, however, was found in the difficulty of getting at the motor for inspection and repairs.

It is the modern practice to attach the motor to the truck rather than to the car body and to treat the car body as one unit and the motor and truck as another. This not only permits the attachment and detachment of open and closed car bodies, but it makes the mounting, inspection, and repair operations much easier, besides adding to the comfort of the car.

The prevailing method at present is to mount the wheels and axles in a frame carrying two crossbars for the suspension of the motors, and heavy springs which receive the weight of the car body and deaden the jolt or oscillation. For some years electric cars of moderate length were equipped with one truck for the whole car, carrying the two motors, and such trucks with the motors geared to them are still in very general use on medium-sized or short cars. But, as the car body has grown in length, one truck has proved insufficient to support the car and carry the motor equipment. The standard practice now is to use two trucks well separated from each other. For high-speed work and sometimes for city service, as will be described later, four motors per car are used, one geared to each axle. Where two motors per car are used, both are sometimes placed on one truck, though the practice differs. In some cities max-



HEAVIEST AMERICAN STREET CARS, ON STREETS OF CHICAGO.

HEAVY CAR OF CHICAGO CITY RAILWAY SYSTEM.

imum traction trucks are used to keep the car body low. These trucks are so designed that one axle of the 4-wheel truck is equipped with larger wheels than the other. This axle carries nearly one-half of the weight of the car and has a single reduction motor geared to it. The other axle has no motor geared to it, and carries only weight enough to keep the wheels securely on the track.

Modern motors.—The motors in general use at the present time for street railway work are of the 4-pole, series-wound, ironclad type. One of the best known, which may be taken as a typical example, has a weight of 1,455 pounds for a rated capacity of 25 horsepower, with a weight of 715 pounds upon the axles to which it is attached. The advances shown in the construction of this machine may be inferred from the fact that a corresponding motor of the same capacity formerly weighed 2,395 pounds, while one of 15 horsepower weighed 1,735 pounds. It is completely incased, so as to be protected against dust and moisture. It is light enough to be lowered into the repair pit in the car barn, and the armature is so short that it can be taken up through the floor of the car by means of a trapdoor. It is hung from the truck in two ways. In the method known as "nose suspension" one end of the motor rests on the axle through its bearings and the other is hung by a crossbar and springs from the truck. In the other, or side bar suspension, there is a side frame resting on springs, carrying the motor by two lugs, one on either side, so placed that the motor is suspended in line with its center of gravity. The armature of this 4-pole machine is made both in the drum form and in the Gramme ring type. Two of the poles are used in connection with two field coils, the other two poles being arranged in a manner known as "consequent." The two field coils are wound on forms and wrapped with waterproof and fireproof material. All the bearings are lined with Babbitt metal and are freely lubricated. The speed reduction is 4.78 between the armature shaft and the car axle—that is, nearly five to one. On these motors, as on all other street railway motors, carbon brushes are used to bear upon the commutator of the armature, and connections between the commutator bars and the armature coils are made by short pieces of flexible cable, joined to the bars by solid cups, so constructed that breakage by vibrations or jolting is avoided.

Controllers.—In order that the action of the motor may be governed and varied, the coil terminals of the motor are brought out by cables to a "controller," or series of spring contacts, pressed against metal surfaces grouped on a vertical cylinder. These surfaces are so arranged and shaped that rotation of the cylinder produces the required combination for operating the two or more motors singly or together, by which the speed of the car is raised or lowered, and for reversing the direction of the car. As these controllers are on the platforms and exposed more or less to the weather, as well as to possible contact with passengers, the mechanism is inclosed in stout metallic casing, which can be easily removed for purposes of inspection. The top of the controller case consists of a brass cover, out of which projects the spindle of the cylinder, which connects with the controller handle. A second handle operates a second and smaller cylinder switch, used for reversing. There is a dial plate on the face of the controller which shows the position of the two cylinders.

The controller in general use is known as the "series parallel" type from the fact that the various degrees of speed and the amount of current consumed are regulated by connecting the motors in series and in parallel, in combination with the resistance which is carried under the car. This resistance consists either of a series of cast-iron girds or of sheet-iron ribbons, generally insulated with mica, the ends of which are brought out to the controllers at either end of the car.

In the actual operation of the car the electric current passes from the trolley pole to the resistance, which is arranged so that it may be cut in or out, and thence to the motors, arranged either in series or in multiple, and thence to the wheels and the track, if the track, as is usually the case, constitutes the return circuit. If this is not the case, and double overhead wires are used, the current returns through a second trolley pole to the return circuit wire. With the controller handle in the first position, as indicated on the dial, the current passes through the resistance, losing in heat a certain portion of the normal pressure or line voltage of 550 volts. With pressure thus reduced the current reaches the motors, which are connected in series—that is, in tandem—and each gets half of the current and starts up slowly. The motorman, moving his lever across the face of the controller dial, cuts out the resistance by a new adjustment of the contacts of the controller. The motors are left in series, taking between them the full pressure of 550 volts. Each is thus getting 275 volts and moving at an appreciably faster rate of speed. At the next step the resistance is again cut in, but the motors, instead of being in tandem on the circuit, are now grouped in multiple or parallel. They both receive the same portion of current from the line and the same voltage, say, 400 volts. Under this voltage the armatures of the motors again revolve faster than before, with an increase in the speed of the car. The last or final position is "full speed ahead," the resistance being entirely cut out and the motors being left in parallel to receive full current and pressure from the line. The number of sections of a controller vary with the grouping of the motors and the division of the resistance. The contacts within the controller are connected with small electro-magnetic coils of wire, which serve as blow-outs for any sparking that occurs when the circuit connections are brought into new groupings. Other safety devices employed are the fuse and the circuit breaker.

The fuse is a short piece of wire of German silver or flat copper of such size and capacity that it will readily be melted by a current strong enough to damage the motor, and the fuse, having a predetermined melting or fusing point, blows as soon as the current reaches the danger point. The melting of the fuse opens the circuit and cuts the current off from the motor. Sometimes the blowing of the fuse has been accompanied by fire, due to the creation of a heavy spark or arc at the points where the fuse metal is attached, but fuse boxes have been secured which are as nearly fireproof as possible, and the fuses themselves are inclosed in cartridge-like cases so as to stifle both fire and noise. The fuse box is usually placed under the car.

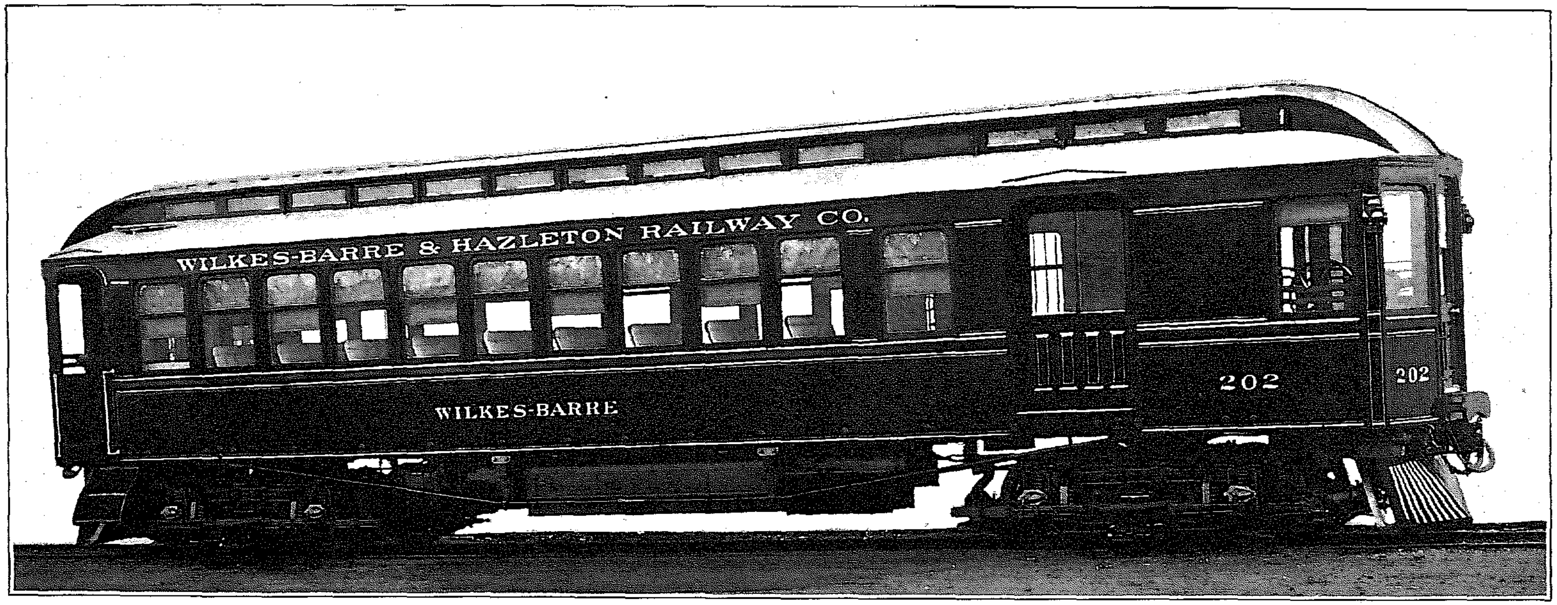
In place of or sometimes in addition to the fuse the cars are protected by what are known as circuit breakers, which perform practically the same function. The circuit breaker is a form of switch controlled by an electro-magnet and is usually placed under the roof of the car platform, where it is readily accessible. It is set to operate automatically at a higher current value than the fuse for the reason that the circuit breaker acts instantaneously, whereas there is an appreciable time required to heat and deflagrate the fuse. The circuit breaker opens the instant the current has reached the point at which it would become dangerous to the motor, and is especially serviceable in protecting the motor against sudden and heavy charges of current, while its use protects the motors against currents of lesser degree which would do them injury if allowed to continue for any length of time.

Number of motors per car.—It has thus far been assumed that two motors were sufficient to propel a street car. On interurban roads, however, and to some extent on elevated roads, a car with four motors has come into use, and the number of such cars is increasing. A number of comparative tests with 4-motor and 2-motor cars were made in 1901 by the Boston Elevated Railway. From the results obtained it did not consider the 4-motor as desirable as the 2-motor cars, all the conditions of service being taken into account. The company equipped one of its standard 25-foot box cars with four motors, which were so connected that each pair was brought in multiple to the controller. A car and truck were similarly equipped with two motors of the same kind. It was found that the 4-motor car took considerably more energy than the 2-motor car to cover the same distance. In one run the energy consumed, as measured by wattmeter in each car, was about 50 per cent greater, although the weight of the 4-motor car was only about 18 per cent greater than that of the 2-motor car. These tests were repeated, with the same motorman handling both cars instead of different men, so as to obtain the same personal equation. The same general results were obtained. The 4-motor car could run at higher speed and carry more load than the 2-motor car. This would mean quicker running time if the tracks were cleared of the slower moving cars. But in view of the great number of cars operated, and the fact that the company was making as fast time as was safe or allowable, except in some places in the suburbs, the technical officials of the road concluded that the greater speed and carrying power of the 4-motor car would be purchased at too high a cost.

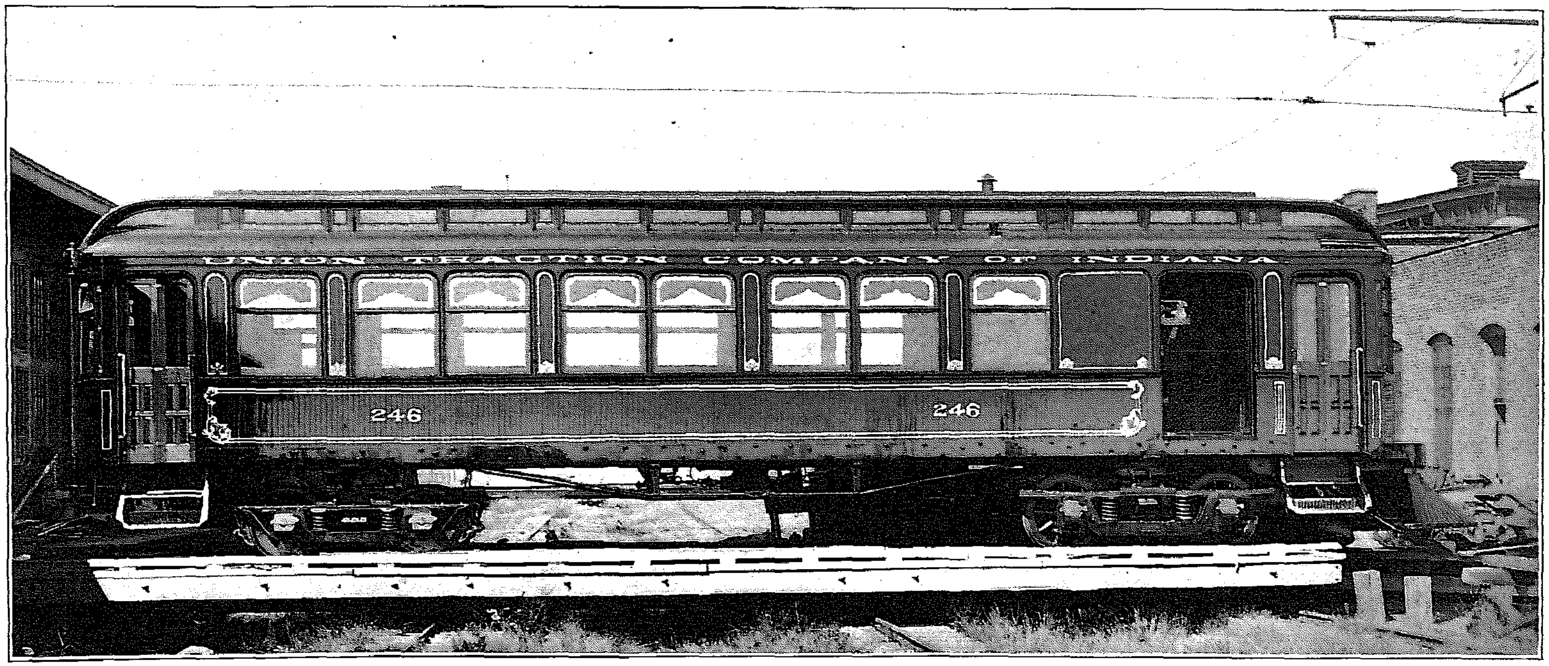
In one thing the 4-motor cars excelled, and that was in the traction. The entire weight of the car was available for adhesion and the drawbar pull was the maximum that could be obtained on any given rail. Traction on the 2-motor car, however, was improved by the use of maximum-traction trucks, in which a large proportion of the weight of the car is carried on the motor axles and very little on the trailer axles, and also by hanging the motors outside the axles instead of between them. This increased the percentage in weight available for traction from 66 to 74 per cent, and reduced to some extent the advantages of 4-motor trucks. An alternative to the use of large, long, and heavy 4-motor cars is to join the cars in trains. This practice is more feasible on an elevated road than on the surface, although there are some instances of the multiple train unit method on the surface lines.

Multiple unit system.—The advantage claimed for the operation of cars in trains of three and four cars, as in the Chicago cable system, rather than singly, is that when the headway is short there is an opportunity to operate more cars on a given length of track without interference. If a four-car train were cut up into four individual units, each traveling within the one minute headway, which prevails frequently for four-car trains, it would mean that the separate individual cars must be operated four to the minute, or at fifteen seconds headway. This is practically what is done on Broadway, New York city, with the electric cars, and at times the headway is even shorter than that. The success in the crowded city streets of Chicago of the four-car train has probably been due to the fact that, as a general thing, the streets in Chicago are unusually wide and straight, so that the other vehicular traffic is not so frequently congested. Whether trains take longer to load and unload than single cars is a disputed question.

Following the example of the cable railways, the elevated railroads of Chicago introduced the multiple unit plan of electric railway operation. This plan involved a different form of controlling equipment from that in use on single cars, so as to make it possible for a train of several cars to operate as a unit. The number of cars in the train might be varied throughout the day, according to the requirements of the traffic, and yet it was necessary to provide for the same speed, and the same quickness of stopping and starting for the largest train



INTERURBAN PASSENGER AND EXPRESS CAR, WILKESBARRE AND HAZLETON RAILWAY.



INTERURBAN CAR IN USE ON UNION TRACTION SYSTEM OF INDIANA.

as for the single car. In the spring of 1898 the South Side Elevated Railroad Company, of Chicago, was equipped for regular service with the first electric multiple unit train ever run, carrying out the ideas and inventions of Mr. Frank J. Sprague. Multiple unit trains of from two to six cars had been experimented with previously at Schenectady, N. Y., and a five-car train had also been tried on the tracks of the Metropolitan Elevated Railroad in Chicago. Since that time the system has been adopted in one form or another on the elevated railroads of New York city, of Brooklyn, and of Boston. Many hundred multiple unit motor cars and "train-line" cars are now in daily use on these systems. A requirement of the multiple unit system is an equipment which will allow the cars to be run in single units from either end of the car, or in any combination from two cars upwards, without regard to the sequence of cars, and with control at will from either end of any car in the combination. This system must be distinguished from the distributed motor control, in which the motors of each car would be handled by the controller of that car without any regard to uniformity and simultaneity of action. While a train could be composed of such motor cars there could be no assurance that the motors would work in harmony. The multiple unit idea involves the contrary principle of distributed motors under a train, subject to a common control, so that all the motors can be controlled simultaneously from a distance, and thus the united action of more motors than could possibly be concentrated on a single car can be secured, with resulting increase of traction and a scientific distribution of various strains. These motor cars, as well as the other cars without motors of their own, if provided with controlling "train lines," can be made up for a train in any combination, without regard to the number of cars or their order. Cars when thus collected into a train can be easily manipulated or controlled from one or more points in the train, usually the head of the train, by the moving of the master switch.

To illustrate the working of the multiple unit system one type of equipment of the Manhattan elevated line in New York city may be considered. The controller consists of two parts: First, a number of electrically operated switches, or contactors, on each car, which constitute the series parallel controller for the motors and vary the starting resistance in the circuit; second, two master controllers on each motor car, one located at either end of the car, either of which serves to control the contactors on that car and all others in the same train. A cable connected to the master controller and to the contactors runs the entire length of the train, and with suitable couplers makes necessary connections between the cars. The current does not pass through the master controller, nor, usually, through the train cable, these parts carrying only the currents which operate the contactors. Each motor car collects its own motor current from the third rail and controls this current in its own contactors. The movement of any master controller sends current to the contactors, since these are wired in parallel to the train cable, thus causing simultaneous movements of all contactors in the train. The action of the motor controllers, or contactors, of all cars at the same time with the movement of the master controller handle insures similar resistance connections and motor combinations on all the cars. The operator knows by the position of the master controller handle the exact position of the contactors on all of the cars and the rate of movement of the contactors. Consequently, the amount of current taken by all of the motors is under his immediate control, just as it is with ordinary hand operated controllers. The motorman is able at will in an emergency to utilize immediately the full power of the motors in either direction.

In case the supply of power to the train is momentarily interrupted for any reason, the contactors all open the motor circuits, but the motor and resistance connections are instantly reset upon the restoration of power, provided the master controller position is unchanged. If the train breaks in two, the current is automatically and instantly cut off from the motors on that part of the train which is not under the control of the motorman, while his ability to control the front part of the train is not affected.

When the master controller is thrown off, both line and ground connections are cut off from the operating coils of the contactors, and none of the train wires, or any of the wires in the train line cable are "alive." To reverse the motors, the master controller is provided with a separate reversing handle, and a mechanical interlocking device prevents this reversing handle from being thrown unless the main handle is in the "off" position. A movement of this reverse handle either forward or back makes connections which throw an electrically operated reverse switch either "forward" or "reverse." This main reversing switch is electrically interlocked, so that it can not be thrown when power is "on." The operating circuit is so arranged that, unless the reverse switch on any car is thrown in the direction indicated by the master controller reverse handle in use, it will be impossible to operate the contactors so as to get any current in the motors on that particular car. A cut-out switch is provided on each car, so that in an emergency all of the contactors on that car may be disconnected from the control circuit. The control operating current at 550-volt line potential is about 2.5 amperes per car for an equipment of two 125-horsepower motors, and the total weight of the control apparatus for this equipment is approximately 2,200 pounds.

The master controller is similar to the ordinary street car controller in method of operation and appearance, although of considerably smaller dimensions. Separate handles for power and reverse are provided. All current for the operation of the several motor controllers passes through the single master controller in use, which takes current directly from the line. A magnetic blow-out is provided, similar to that used on standard street car controllers. An automatic open-circuiting device is provided in the master controller, whereby, in case the motorman releases the master-controller handle in any "on" position, the control circuit to the motor controllers is instantly opened on auxiliary contacts. This result is obtained by mounting the operating mechanism for the auxiliary safety device loosely on the main shaft and providing it with a spring, which, when released, is returned to the "off" position without necessitating the movement of the entire cylinder or handle; thus the device is entirely separate and distinct in its action from the main cylinder.

The motor controller for each car consists of 13 electrically operated switches, called contactors, and an electrically operated reversing switch, which reverses the armature leads of the motors. Each contactor consists of a movable arm, carrying a finger, which makes contact with a fixed terminal finger, and a coil supplied with current from the master controller for moving the arm. The contactor is so designed that the motor circuit is closed only when current is flowing through the coil. Gravity, combined with spring action of the finger, causes the contactor to open as soon as the master controller circuit is interrupted. The contactor has an efficient and powerful magnetic blow-out. The different contactors are practically identical, and the few parts which are subject to burning and wear are so constructed as to be readily replaced.

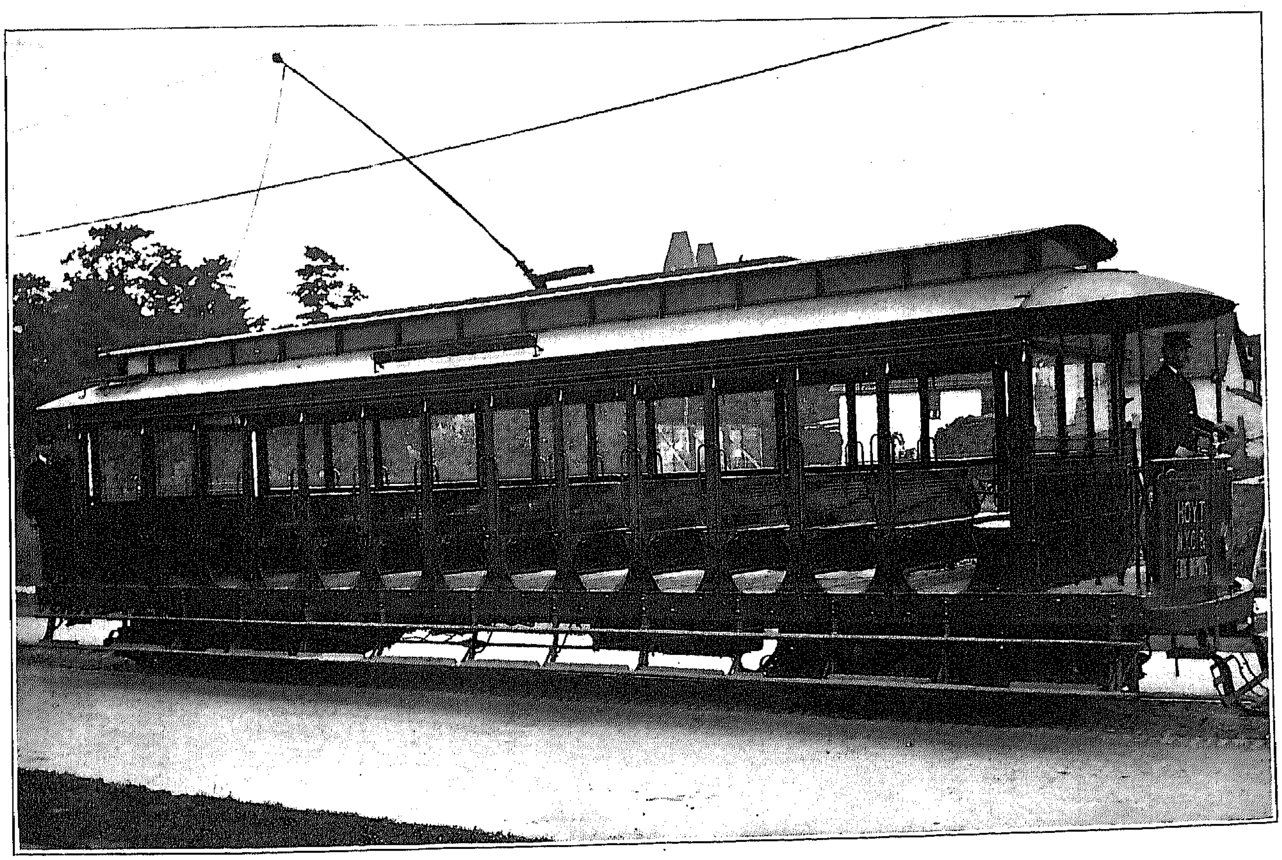
The general design of the motor reversing switch or reverser is somewhat similar to the ordinary cylindrical reversing switch, with the addition of the electro-magnets which turn it to either the forward or the reverse position. The operating coils are similar to the ones used on the contactors.

The coupling between the cars consists of sockets and a short "jumper" cable, with a plug at either end. The sockets on the car contain a number of insulated metallic contacts, which are the terminals of the wires in the train line. This socket is shaped to receive the plug on the end of the cable. The plug contains the necessary insulated contacts to make the required connections, and is so shaped that it can be inserted into the socket in only one way, thus insuring the same series of connections each time two cars are coupled together. The couplers are provided with spring catches, which maintain contact under normal conditions, but permit them to be released immediately in case the train breaks in two. A special cable made up of different colored, individual, insulated wires is used whenever possible to make control circuit connections between the various pieces of apparatus, a similar cable being used for the connection between the coupler plugs.

An important differentiation in some respects from the apparatus thus described has been installed on the Brooklyn Rapid Transit Company's elevated system. The supply of current through the third rail, and that supplied through the connections of the low-voltage control circuits are the only sources of power which have to be considered in train operation. In this apparatus compressed air is used in connection with a set of storage batteries. Only seven battery wires are required for the train line or cable, so that the cable carries a pressure of only 14 volts. This dispenses with high-voltage wires on the train cars and high-voltage coupling everywhere on the system. The master controller and the air-brake operating valve are mounted on the inside end panel of the motorman's cab. The master controller handle is fitted with a spring return which makes it a "dead man's handle," it being so constructed that should the motorman remove his hand at any time from the controller handle, the brakes are at once applied automatically unless the reversing handle has first been turned to the center position. By similar mechanism, if the brakes are applied while the current is still on, the current is automatically cut off. This is accomplished when setting the brakes by means of a connection between the spring return handle and the air brake system, while the release of brakes is effected by a connection between the air brake system and a small air cylinder, the piston of which opens the storage battery circuit.

To insure uninterrupted service from the storage battery used in operating the electro-pneumatic switch, there are two sets of batteries of seven cells each, which, like every other part of the system, except the master controller and the battery switches, are carried beneath the car floor. The controller itself comprises 13 unit switches, arranged radially in the turret, and protected by a sliding cylindrical case. These individual switches are operated by pneumatic pistons controlled by electro-pneumatic valves, operating against a spring pressure of 70 pounds, so that a very decided motion is given to the circuit breaker. The 13 switches have a common magnetic blow-out coil, located at their center, of which the spider arms of the individual switches constitute the pole piece. The danger of the welding or sticking of the contact surfaces is avoided by the pressure of air against a spring. Moreover, the switch finger levers are made flexible, so that when drawn up by pneumatic pressure and released by spring pressure they produce a slight rubbing movement of the contact surface and help to prevent any possible welding. The reverse switch is of the usual type, with copper contacts operated by two air cylinders controlled by electro-pneumatic valves running from the reverse cylinder of the master controller. This reverse switch is placed as near the motor truck as possible to reduce the length of the wire, and beside it is the limit switch governing the speed. The total weight of the complete apparatus, inclusive of the battery, is over 1,700 pounds. All

INTERURBAN CAR ON CLEVELAND, ELYRIA AND WESTERN RAILWAY.



LONG TYPE OF OPEN CAR, IN USE AT BUFFALO, NEW YORK.

the circuits are run in electro-bestos conduits. The system has been constructed with the idea of securing absolute and instantaneous control, with the minimum liability to collision, fire, or other casualty. The vital importance of the car controllers justifies the immense amount of money and energy which has been expended in devising the modern systems. Brief reference to larger motors will be made in the chapter on interurban railway equipment.

V.

THE OVERHEAD TROLLEY CONTACT.

The devices for conducting the current from overhead wires into the cars are details which could not at any stage of the development be considered independently, but had to be developed in relation to the methods of suspending overhead wires and of employing the overhead frogs and switches along which the contacting device has to travel. Some of the earlier trolley devices traveled along the top of the wire, but this was soon found to be an inconvenient and inexpedient method. The overhead devices for making a side contact were also found impracticable, as, for example, those used on the electric road at Offenbach, Germany, where a split tube was employed, at the side of the road, the contact device sliding along inside the tube.

Instances of the early style of overrunning trolley in this country and Canada were due to Mr. Van Depoele, and one or two of them were in use until recent years; for example, at St. Catherines, Canada, where one form employed was exactly like the underrunning trolley, but had a heavy weight attached to a cord to steady it in position on the wire. Such overrunning contact devices were connected with the cars by flexible cords, and when cars passed the cords were exchanged or one of them was lifted from the wire by the car conductor by means of a long wooden fork, kept on the car for that purpose. As soon as resort was had to the trolley wheel pressing upward under the wire (the underrunning contact), it became necessary to employ a pole extending upward from the car roof to hold the wheel firmly in position, and in this manner, through a variety of forms of pole, base, and swiveling mechanism, was evolved the modern trolley seen on top of all such cars in the United States. The trolley pole now used is of tubular steel. The trolley wheels are usually of fairly hard copper. The pressure of the trolley wheel against the contact wire is from 16 to 20 pounds, depending upon the style of the wheel; and the wheel itself, which is from 4½ to 6 inches in diameter, weighs from 3 to 4½ pounds. The average life of the lighter wheel is 5,000 to 8,000 miles, the wheel taking up the wear rather than the wire; but the 6-inch wheels have been known to endure for from 12,000 to 15,000 miles. Precautions are now taken to prevent the pole swinging around and doing damage to the overhead construction when the trolley wheel by accident leaves the wire. For this purpose devices known as trolley retrievers and trolley catchers are employed. The retriever is so constructed that it pulls the trolley pole down clear of all the wires as soon as the wheel leaves the trolley wire. It is usual to have a rope, attached to the trolley pole, by means of which the conductor or motorman can adjust the trolley pole from time to time as may be required.

VI.

BRAKES.

The statistics regarding the extent to which different kinds of brakes have been installed on street railway cars, included in Table 95, show that 63,690 cars, or 95.4 per cent of the aggregate number, were reported as equipped with hand brakes, and 7,905, or 11.8 per cent, with air brakes, including those in which the air pumps are driven by electric motors, and 5,148, or 7.7 per cent, with other varieties of mechanical brakes. It is of course evident from these figures that many cars are provided with brakes of more than one kind.

The detailed statistics show a very general distribution of hand braked cars. In New York state, for example, all but 5 of the 96 companies reported that they had at least some cars equipped with hand brakes. Out of a total of 14,040 cars reported for the state 13,805 were equipped with hand brakes. The same conditions prevailed in Pennsylvania where 6,972 out of 7,058 cars had hand brakes; in Massachusetts where 8,274 out of 8,310; in Illinois where 5,790 out of 7,778; and in California where 2,016 out of 2,056 cars were reported with hand brakes.

The air braked cars were more generally distributed than might perhaps be expected, cars of this character being reported from all the states except Arizona, Arkansas, District of Columbia, Idaho, Kansas, Mississippi, Nebraska, New Mexico, and South Dakota. The great majority of these cars, however, were reported from a few of the principal states—1,529 from Illinois, 1,207 from Massachusetts, 2,070 from New York, 445 from Ohio, and 1,064 from Pennsylvania. Of the number in these states, again the majority were reported by the larger city systems, as, for example, New York city, Brooklyn, Chicago, Boston, and Philadelphia. The Metropolitan or Interurban system in New York city reported every one of its cars as hand braked, so that the large figures in that area are in reality those of the Manhattan Elevated, with 1,331 cars.

In all of the earlier cars the brake applied to the wheels was invariably that operated by a hand lever. The brake handle was connected by a chain and a system of levers with brake "shoes" on the wheels, the handle usually moving 25 inches for a quarter-inch movement of the shoes, so that with 2 inches slack in the chain the handle would have to make nearly two revolutions, in addition to the revolutions required for taking up the slack, before the shoe was brought against the face of the wheel. This brake had the advantage of putting little strain upon the driver and the horses, but owing to its rather slow operation it resulted in "flatting" the wheels, which was a source of great annoyance to the company and discomfort to the passengers. Some brakes, called track brakes, are operated by being pressed against the rail. The introduction of what are generally known as mechanical brakes has lessened the amount of "skidding" and the wear and tear of the wheels, and has given the driver a more instant control of his car. Indeed, it would probably be impossible to operate the heavy cars of modern type without the powerful mechanical brakes which are now employed. It is estimated that with modern braking methods brake shoes should last about 5,000 car miles, and the usual chilled iron wheels 35,000 car miles, without renewal. An average brake shoe of 21 pounds is allowed to remain in use until the block has had a wear of some 10 or 12 pounds. These are average figures, the actual figures varying greatly in practice. The power from the power brake handle is conveyed to the shoe by a variety of forms of rigging. In one form of momentum friction brake the brake staff, instead of directly transmitting the power necessary to pull the brake shoe up against the wheels, is connected through the brake chain to the drum sleeve of one of the axles. This drum is not keyed to the axle and does not turn with it except when a stop is to be made. When it is desired to stop the car the edge of the drum, which is in the form of a disk, is pressed by a series of levers against a corresponding disk on the inside of the car wheel, a leather washer being placed between the two disks in order to take up the wear. The friction due to the pressure of the drum against the car wheel causes the drum to revolve, thus winding up the chain and setting the brake.

As is shown by the statistics a large number of modern street cars is equipped with air brakes or electric and magnetic brakes. In the city railways in the Eastern states, where short cars have been largely retained on account of narrow and crooked streets, hand brakes are common, while with long or high-speed cars air or other power brakes are almost universal. The supply of air is usually produced by independent motor compressors carried on the individual cars, but in a few cases central compressor plants driven by steam or by electric motors have been installed. Where this is done the car reservoir carries a reserve storage supply of air at 300 pounds pressure and a working supply at from 20 to 50 pounds pressure, the amount depending mainly upon the weight and speed of the car. An average of 500 stops may be made on one charge.

Where the compressor is carried on the car, it is usually driven by an independent motor provided with an automatic switch, which is so acted upon by the air pressure in the reservoir that it throws the motor in and out of operation as the pressure in the reservoir falls and rises. In another type the compressor pump is geared to one of the car axles in such a way that the revolutions of the axle of the moving car supply power to work the pumps. When the reservoir is fully charged the gearing is released and the pump stops acting.

In one system of electro-magnetic braking a circular electro-magnetic brake shoe is rendered magnetic by the current from the motors in such a way that it is drawn powerfully against the face of a disk on the car axle. This brake serves for emergency stops as well as for all service stops, but up to the present time it has not been widely used. Another system of electro-magnetic braking includes a double or split track shoe of novel construction, combined with a powerful electro-magnet. The magnet, when energized by a current from the car motor, acting temporarily as a generator, brakes the car by being strongly attracted to the rails over which the car is passing. Lever connections may also be established between the electro-magnetic brake shoe system and the wheel brake shoes, so that when the track shoes are set the magnetic brakes are also set against the wheels, the effect being so adjusted and graduated that no greater brake pressure can be applied to the wheels than they can withstand without skidding.

The Pittsburg Railways Company has adopted magnetic brakes for open and closed cars, while the United Railroads of San Francisco on combination cars, which operate on the steep grades of that city, employ straight air, wheel, and track brakes.

The subject of brakes has been considered carefully by the authorities in various states and communities, with the object of lessening the number of accidents, which might be avoided if the cars were under better control. The board of railroad commissioners of the state of New York in 1899 authorized a public competitive test of brakes for surface cars. The commission issued a notice of the test to owners of brakes for surface cars, in response to which 26 applications were received, all of which, with one exception, were accepted by the commission.

Elaborate methods of testing were devised, and on each car 14 average speed records were taken—3 at 8 miles per hour, 3 at 12 miles, 3 at 15 miles, 3 at 16 miles, and 2 at 16 miles with sand. It had been the intention to carry the tests to higher speeds, but these did not prove feasible with the motor equipment used. The record of the tests made by the commission constituted an elaborate report. On the basis of the tests the board decided that except in special cases, where the liability to accident is very remote, the ordinary single chain and spindle hand brakes then and still generally used should be replaced by some one of the mechanical or power brakes which were submitted and tested. The board did not recommend any particular brake for any class of service, but left the selection to the judgment of the railroad officials themselves, reserving the right to exercise fully its power under the law to require of the companies the use of sufficient and safe equipment for the public service.

The tests related not only to the average length of track covered before the stop was effected by each brake at the different rates of speed, and to the skidding of wheels, but also to the reliability and simplicity of the system, the liability of the brakes to act when they should not do so, the ease with which the brake could be operated by an ordinary motorman, and the cost of equipment and maintenance. First in the order of worth was an electric brake. This brake, operated by the trolley current, consisted of a series of magnets with armatures at varying distances, mounted loosely on the same rod, and placed in such a way that the attraction of the armature nearest to the core carried with it the armature next in distance from the core to a point of greater magnetization, and so on, each armature acting upon the next and thus creating a long and powerful pull. The rod upon which these armatures were arranged formed part of the ordinary brake rod, and the brake could be applied to the ordinary spindle hand brake. The movement of the brake handle set the electric brake in operation, but this could be done without interference from the electrical portion of the brake, so that in case of failure or interruption of current the brake could be set by hand. The hand brake being naturally under test at all times when the electric brake was in use, its working condition was insured in case of some failure of current from the trolley line. The device took but 5 amperes of current. With the cars under test this brake made a stop, for all speeds, in an average distance of 58.83 feet. At 16 miles an hour on ordinary track the cars stopped in 72.33 feet in 9.35 seconds, and at a speed of 16 miles an hour with sanded track in 73.08 feet and in 8.92 seconds. The brake which ran closest to this in the tests was the momentum friction brake, the friction device being placed on one of the axles of the car. This brake showed stops at all speeds in an average distance of 66.71 feet. It can not be said, however, that any great weight has been attached to these tests.

Aside from or in addition to the brakes there are other parts of the operating construction which are in universal use. One of these is the gong operated by the pressure of the motorman's foot, and sounding its warning insistently in crowded streets. Another device upon or within the car itself is the safety gate, with which motor cars in some cities have been equipped, as, for example, at Minneapolis and St. Paul, Minn. This gate being under the control of the motorman, is opened promptly when the car comes to a standstill and is closed just before the power is applied for starting. On many open cars are bars which are let down at the same time that the side step is thrown back on either side of the car, so that the car can not be freely entered or left on the side next to the other track. In some closed cars it is the custom to place bars or rails or netting at the open windows to prevent accidents to passengers who might protrude elbows or heads from the apertures at dangerous places, or attempt to use the windows as a means of entrance or exit.

VII.

CAR FENDERS.

A conspicuous feature of cable and electric railway work has been the car fender, the use of which has been required by ordinance in a great many cities, but the adoption of which is by no means universally favored among street railway managers. The purpose of the fender placed at the front of the car, or immediately in front of the wheels, is to push aside or catch up and hold in safety persons who might otherwise be run over. A variety of such car fenders have been introduced, some of them exhibiting great ingenuity. Sometimes the fender is held up on the front of the car and can be released by the motorman in case of an emergency, but this is regarded as open to the objection that when the occasion for its use arises the motorman may not have sufficient presence of mind to do what is required of him, and the car may run over the person before the fender can be lowered. A common type is that which is carried in front of the car a few inches above the track, and which, if desired, can be folded up or carried around to the other end of the car for the return trip. Such fenders have more or less the form of a net, being constructed usually of light slats of metal, with a stout outside rim.

It is objected that many of these life guards are just as apt to cause accidents as to prevent them, projecting, as they do, several feet in front of the car. This objection is sometimes met by arranging the fender so that it collapses when not in use, and is drawn back under the car, whence it is released in case of danger. Few or none of these more elaborate devices are in practical use. The results of experience would seem to show that in most cases where the speed of the car is slightly reduced the fender will pick up without harm or injury persons who, without the fender, would have gone under the car. Even when the car is still under rapid headway, the injury from the fender is not apt to be as great as the injury from a car without such equipment. On Broadway, in New York city, the cars are equipped with fenders carried under the platform, which are technically known as wheel guards. The objection to the projecting fender in such thoroughfares is that because of the density of traffic their general use would add seriously to the obstruction of the streets. Pedestrians and carriages now crossing freely between cars without fenders would, if the fenders were in use, often find passage difficult or impossible.

There are four or five types of fenders in general use in the United States. One of these as used on cars whose sills are of medium height above the track, is of curved form, and when not in use is held up against the rear dashboard. The upper crossbar of the fender can be adjusted on low cars to a position 15 to 17 inches above the track, and when dropped its front rests directly on the surface of the street, so that no object can pass under it. Sometimes it has at each side a rubber covered spring to prevent a body from being thrown to one side. In cross country and interurban cars this type of fender is made large enough and strong enough to pick up a horse and carry it until the car comes to a stop. In all these fenders there is a cushion against the dashboard, made of strips of strong spring metal, which prevents the object struck from coming into contact with any hard surface on the front of the car. These fenders are dropped by a pedal on the platform, operated by the motorman's foot.

Another type of fender in use in some large cities is composed also of metal slats. The platform of the fender stands at an angle of 45 degrees, with a rubber hose 4 inches in diameter stretching across the lower end, which is usually about 3 inches from the ground. When a person is struck by the fender, the platform, which swings on a pivot, falls back and brings the outer end with its rubber tube about 20 inches above the ground, while the rear end, nearer the car, is 6 to 8 inches lower. Thus a basket or pocket is formed which carries the person safely until the car can be stopped. The back guard is made of a steel spring placed several inches lower. If the car is going at great speed the body will strike against the guard, but can not be thrown out again onto the track. This fender is always in position and requires no action on the part of the motorman.

One type of nonrigid car fender in use to some extent, based upon the principle of receding action, has several plates or detached portions like shutters across its farther end to conform to uneven surfaces, and offset the effects of the oscillation of the car. The receptacle back of these plates is composed of metal network. When in use, the projection of the fender beyond the car is slight; when not in use, it can be pushed underneath the car. Another form of automatic car fender has two automatic release devices in addition to the ordinary foot drop in common use. One of these automatic devices consists of a front trip bar, which is forced back on coming into contact with obstructions. The transmission through lever and cranks of the motion caused by the impact operates the foot pawl of the fender. When this trip bar might prove inconvenient, as in the case of the track being covered with snow, it can be turned aside against the fender and the other automatic device employed in its place. This second automatic device is operated by the impact of the body falling against the fender cradle or netting. The contact with the fender pulls forward rocker arms attached to levers which operate the foot pawl. The complete fender is attached to a car by iron bolts connected with the outside sills of the car platform. It folds up compactly without interference with the car couplings or headlight, and can be used on various styles of cars. The front of the fender is made of rubber tubing, with a steel cable passing through it.

According to Table 95, of the 66,784 cars reported, 60,290 were passenger cars, of which 43,273, or about two-thirds, were equipped with fenders. The state of New York, with a total of 14,040 cars, reported 7,123 equipped with fenders. The small proportion equipped with this device is due to the fact that cars of the elevated systems are operated in trains and need no fenders. In Massachusetts 7,021 cars out of 8,310 were reported with fender equipment. In Illinois 3,214 cars out of 7,778, and in Pennsylvania 5,693 out of 7,058 are equipped with such a device.

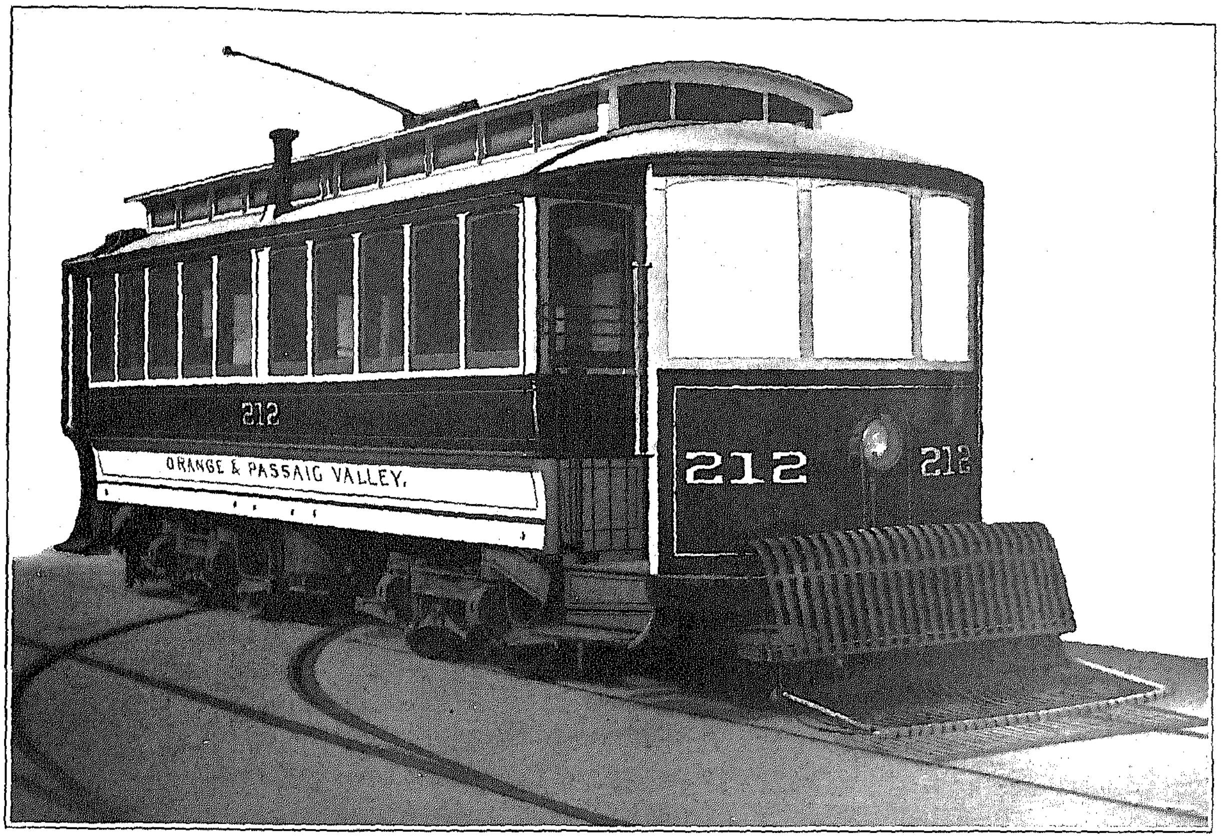
VIII.

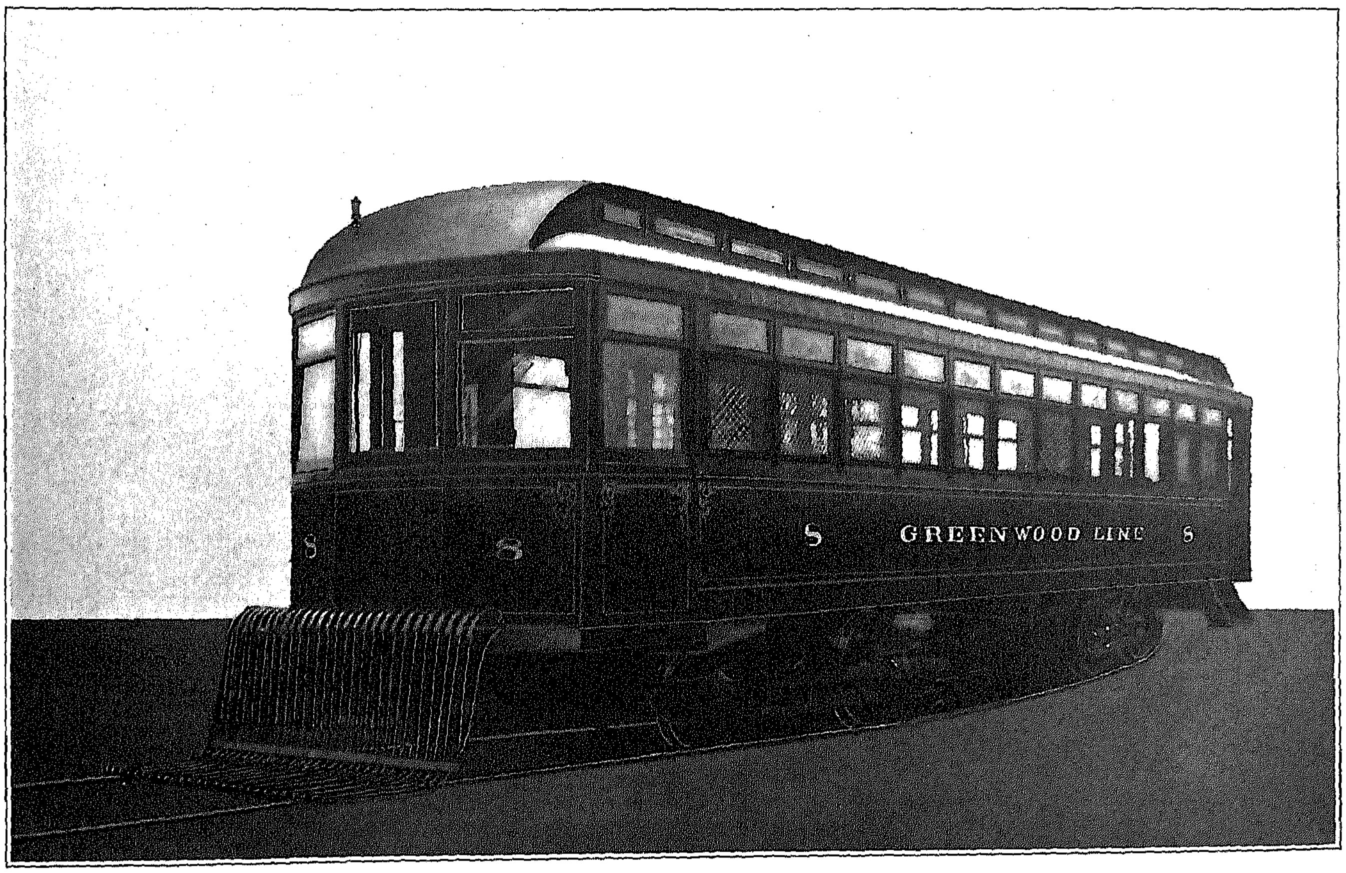
CAR LIGHTING.

Of the total number of cars reported 62,369, or 93.4 per cent, were lighted in some manner. Out of this number 55,703 were lighted by electricity and 6,666, including all horse cars, were lighted by oil or gas. The detailed figures for states and companies are shown in Table 95. A number of states report all or nearly all of their cars lighted by electricity. Among these states are Connecticut, Iowa, Massachusetts, Minnesota, New Jersey, Ohio, Pennsylvania, Rhode Island, Virginia, and Wisconsin. Cars lighted by electricity are found exclusively on roads using electricity as a motive power, the supply of current thus being rendered easy and cheap. The change in the manner of lighting cars therefore closely followed the change in motive power.

The unsatisfactory oil lamp was in the beginning the only method of car lighting. This lamp was superseded on some of the cable lines by compressed gas, the illuminant commonly employed on steam railways. With the introduction of electric traction it was found to be an easy matter to light the cars by taking the current from the same circuit as that which supplied the motors. The light is still somewhat flickering from the occasional variations of voltage, interruptions of the trolley contact, or jolting at the switches, when for an instant or two the current is lost. This has sometimes been prevented by the installation of storage batteries on the cars which could be fed from the line, but this practice has been given up as the advantages did not compensate for the expense and trouble.

The lights usually installed are 16 candlepower in multiples of 5. The use of the lamps in groups or multiples of 5 is due to the fact that the average voltage or current pressure of the line is about 550 volts, and as the ordinary incandescent lamp takes about 110 volts a group of 5 of them will absorb the trolley line voltage





TYPES OF STREET RAILWAY CAR FENDERS.

without the necessity of employing extra resistance. The 5 lights are arranged in series across the motor circuit and are provided with a fuse and cut-off switch. At first ordinary incandescent lamps were used, but as jolting broke the filaments it is now the practice to "anchor" the filament by a small hook sealed into the lower larger end of the glass bulb. In some instances the lights are not merely distributed within the car, but out on the platforms, and the headlights are also usually electric. The electric headlight usually consists of a large incandescent lamp aided by a powerful reflector. A variation of this light consists in the utilization of what is known as the "inclosed" arc light, including an inner globe immediately around the arc. This is associated either with a rheostat or with a small cluster of incandescent lamps, so that either or both can be employed in accordance with the amount of light required. The car has to be specially wired for such purposes. In the early stages of development the circuits were simply run with ordinary insulated wire held down with staples, cleats, or molding. Even the main circuits from the trolley line to the motors were carried through without much protection, but it is now a general practice to inclose all these circuits in conduit, usually of iron pipe.

IX.

CAR HEATING.

It appears from Table 95 that in 1902, 30,159 cars, or about one-half of the total number of cars in the United States, had provisions for heating. Of this number 19,021 or 63.1 per cent were heated by electrical apparatus, while 11,138 or 36.9 per cent were heated by stoves, hot water, or other means. Electrical heating is necessarily limited to street railway systems and cars electrically equipped, the heat being derived from the circuits supplying current to the motors. It will be noticed, however, that some companies using electricity as the motive power still employ stoves for heating.

In northern climates in the old-fashioned horse cars, the coal stove was long used in winter. The car was so arranged that a stove could be introduced in the middle of one of the seats, with a pipe running up through the roof. The stove occupied space which would otherwise have been available for seating; it did not successfully heat the car, and fires frequently broke out.

Gas and oil stoves on a somewhat similar plan were also tried, and indirect methods of steam and hot water heating have been extensively experimented with, especially on interurban lines. The objections to this latter plan, however, have been the loss of time involved in refilling the steam and water reservoirs and the large incidental waste. Hot water heaters have been largely used on long interurban cars.

The usual method of heating cars electrically is to place the heaters—composed of coils of resistance wire in various forms and grouping—beneath the seats at regular intervals, the fronts of the radiators being protected by grating and the switches being so arranged that the car conductor can throw in some or all of the heaters, as required.

The circulation of air through the resistance coils in which the passage of current is engendering heat is so rapid that while the flow of warm air from the top of the heater is large in volume the air itself is not hot enough to heat unduly the front casing of the seat. In a test of an electric heater an overload of 25 per cent of current was put through it, the casing being entirely covered with damp clothes, such as passengers might wear. The current was left on for a half hour, and at the end of this time there was not the slightest indication of burning or discoloration of fabrics. It has been shown by tests that with an ordinary consumption of current of 3,160 watts a car with 4 doors and 16 windows, containing a little more than 1,000 cubic feet, traveling in an outside temperature of 28 degrees Fahrenheit, can maintain a temperature of 54 degrees Fahrenheit. Assuming that this degree of heat and consumption of current were maintained throughout the day of eighteen hours, and that the current cost the company about 1 cent per kilowatt hour, a cost for heating such a car would be slightly over 50 cents per day. The actual cost, however, would probably average well below this figure.

X.

REGISTRATION OF FARES.

The collection and registration of car fares has always been an important problem with the street railway companies, the one great aim, of course, being to secure payment from all passengers and to prevent the diversion of revenue from the tills of the company to the pockets of dishonest conductors. The task becomes a relatively easy one where a ticket system is employed, requiring the passenger to buy one ticket for a continuous ride, and to deposit that ticket with the conductor or in some appropriate receptacle. This is the plan that has been followed for many years on the Manhattan Elevated system in New York city. Each passenger is required to deposit a ticket in the box at the entrance to the platform, under the charge of the regular custodian. This method has been varied in some of the elevated stations by the introduction of a registering turnstile; but where the volume of traffic is great, as it is at so many elevated stations during rush hours, turnstiles would not be tolerated, and even at the smaller stations they do not appear to have proved entirely successful.

In Europe it is the common practice to issue tickets, not only for elevated and subway railways, but also for the regular street car and omnibus lines. In America it is thought that the travel on street cars is too much of a "come and go" character to permit the use of a ticket system, and hence the collection and registration of fares usually depends wholly upon the conductor.

In the early days of the bobtail car the driver was also conductor and made change as well as managed his horses, the fares being deposited under his eye in a small lock box adjacent to the front platform—the box being so placed as to be seen by the passengers. This method still obtains in a few places, but its many inconveniences caused it to give place to the old portable bell punch, which enabled companies to settle with their conductors upon the basis of the showing made by the punch rather than upon the basis of the conductors' report of the number of fares collected. It soon became evident, however, that in a crowded car a conductor is likely to miss some fares, either from the unwillingness of the passengers to pay, or from the inability or unwillingness of the conductor to make collections. Although the conductor carried a punch, it did not follow that he would use it every time a 5-cent fare was collected, nor was it absolutely certain that he would ring up the fares on the company's bell punch instead of on a substitute one provided by himself. To remedy these difficulties, companies soon began to use the stationary clock register or counting machine, which is placed in a conspicuous part of the car where every passenger can see it, and upon which fares collected are supposed to be duly "rung up." The fare register system has now become universal throughout the country. Many modifications and improvements have been made to adapt the register more perfectly to varying conditions of service and to the varying practice in different places in the matter of collecting fares and issuing transfers. To obviate the disadvantages of the single register system, which, of course, would count only one class of collection, namely, so many 5-cent cash fares, the double register came into vogue, allowing other combinations of accounting, and consisting virtually of two single registers in one case.

When it is considered that the street railways are carrying at least 6,000,000,000 passengers a year, all of whose fares have to be brought to book by means of the register, it will be seen that the accounting and mechanical problems involved are of no mean nature. To show to what extent ingenuity in this direction has been carried in the way of making a street car register perform various functions, such as the registering, indicating, and printing a statement of collections—in other words, performing the full duty of a cash register and something more—the developments up to date deserve note.

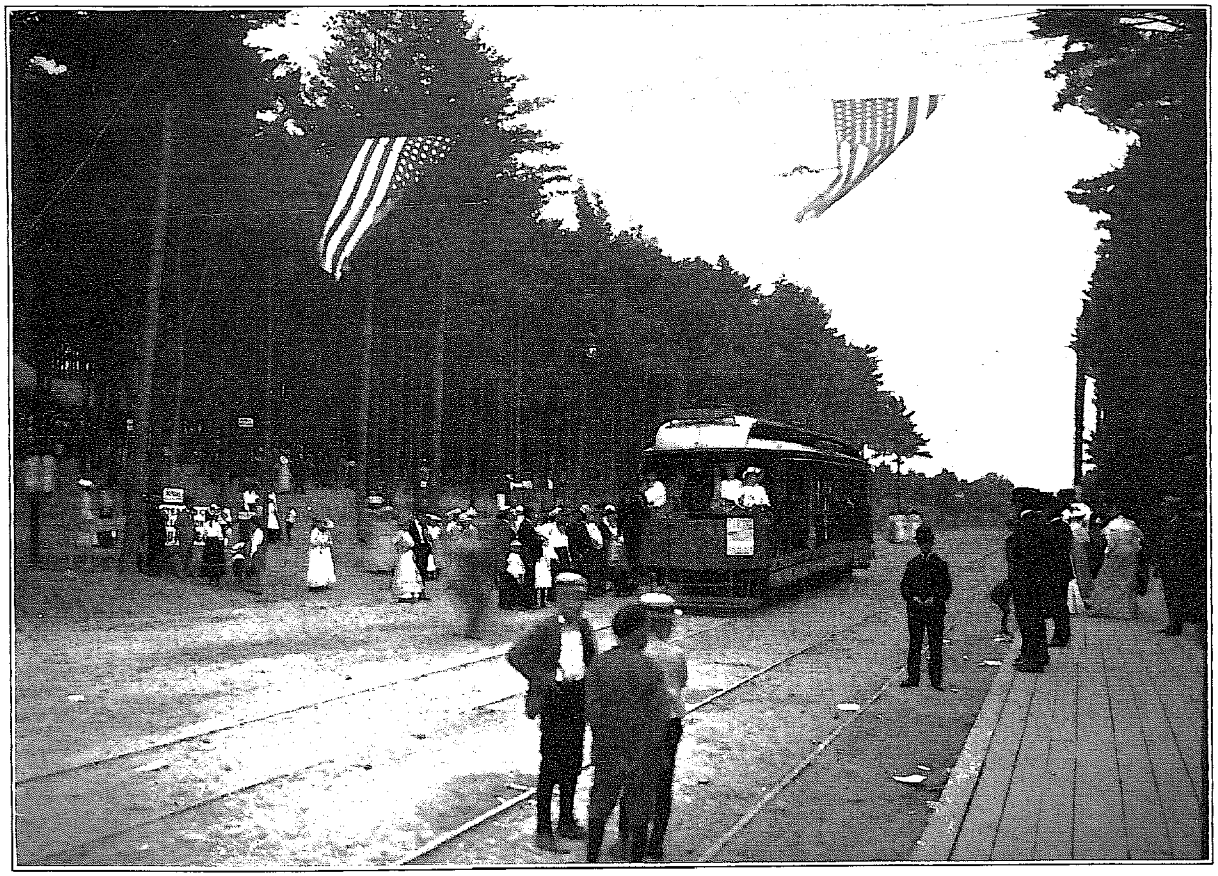
Registers now on the market and largely employed by street railway companies make a distinct registration of each fare collected, the different kinds of fares being registered separately. They also keep a printed record of the collections of each conductor and of the total number of all fares, irrespective of class, as well as the number of fares in each class for each half trip. They further print the number of registrations, the trip number, the date of the day and month, the direction in which the car is going, the name of the conductor, and a duplicate or triplicate summary record of the day's business, irrespective of the number of conductors who operate it. When not in service the register may be locked, and can not be operated until the conductor's badge number is printed upon the statement inclosed in the register. This device, then, without exceeding a practicable limit of size, acts as an adding machine, a cash register, a time clock, and a printing press, all applied to the task of insuring for the company the fullest collection of its revenues. Few companies, to be sure, use or greatly need registers that have been brought to any such degree of complexity of mechanism, but the instrument none the less illustrates in an interesting way the attention and inventiveness that have been applied to every branch of the street railway business.

XI.

STREET RAILWAY PASSENGER STATIONS.

The statistics for street railway passenger stations refer to the separate buildings, or public shelters, at which passengers wait to take cars, pay fares, or secure transfers. They do not include stopping points, or open-air stations along the line where passengers board the cars. There are 2,076 street railway stations reported. A large number of these were reported by elevated railways, by railways formerly operated by steam, and by fast long interurban railways. Until within the last few years it has been the universal practice to permit passengers to board or leave a car at any street corner, in contrast with the steam railway practice of running trains between fixed points more or less widely apart. A number of street railways have long furnished waiting rooms at their termini, however, or at important intersecting points, and elevated and underground roads have been operated on the station plan. In order to secure a speedier schedule, several street railways have adopted the practice of putting up signs on poles at points several blocks apart where the cars would stop, the points being located with reference to traffic demands. These points have very rarely had shelters connected with them. Within the last year, however, the growth of interurban roads has necessitated the construction and maintenance of a large number of passenger stations, and these stations have either been connected with freight and baggage rooms or with substations that contain apparatus for furnishing current to the track.

The further differentiation of interurban roads from ordinary street railway lines within cities led to the establishment of interurban waiting rooms, both inside and outside of city limits. The final step has been the construction of union terminal stations for street railway traffic. While this report has been in preparation,



A TYPICAL TROLLEY PARK IN MASSACHUSETTS.

an extensive and costly terminal station has been erected at Indianapolis, Ind., for the use of nine interurban lines. At Milwaukee, Wis., the street railway company has erected a substantial steel frame structure to be used as an interurban terminal station and general waiting room, office building, and storehouse for reserve cars. At Detroit, Mich., there is a common waiting room for all interurban lines, and at Muncie, Ind., an important interurban center, a terminal building has been built for the same purpose. At Cleveland, Ohio, one of the most important interurban centers of the country, a large station has been erected on the public square in the heart of the city, where waiting sheds have been in use for some time. The building is 62 feet long and 13 feet wide, the roof extending beyond the walls 12 feet at the ends and 4 feet on the sides. It is of brick, with stone copings, the framework of structural steel, and the roof of tile. The ticket office and check rooms are so located as to divide the interior into two rooms, the smaller being a smoking room and the larger a passenger room. Doors at the ends open to stone steps leading to the basement, where are toilet rooms for men and women. Its cost was about $10,000, each of the five interurban companies that use the building paying one-seventh of the cost and the city company two-sevenths. While all stations are not as well located as the station in Cleveland, many of them are convenient of access. The station at Indianapolis is located one block from the street railway center, and that in Milwaukee but one block from the principal street in the city. The agreement with the authorities provided that the Cleveland station should be erected in accordance with plans approved by the city, without any expense whatsoever to the municipality for construction and maintenance and to become the property of the city as soon as completed. The railways are given the right to use this station without any assurance as to length of occupancy. The interurban roads which are to use the station have no trackage in Cleveland, but run their cars into the city over the tracks of the Cleveland Electric Railway Company. The agreement provides that nothing but tickets may be sold in the station.

Admirable types of passenger and substations may be found on many of the interurban roads. In the vicinity of Cincinnati, Ohio, for example, two very attractive substations are located on the Suburban Railway. The one at Forestville, Ohio, is of stone and buff pressed brick with stone trimmings and ornamental tile roof, two stories high in the center with a one-story wing at each end. The upper floor of the central part is arranged with a suite of five rooms for the attendant of the substation, while the lower floor is occupied by the alternating current transformers and rotary converters. Each of the wings is 25 feet in length, one being a passenger waiting room, and the other an express office. On many of the interurban roads the stations resemble in general appearance and design the way stations on steam railway lines. A number of the stations referred to in the report are those connected with the parks and pleasure grounds operated in connection with street railways, or reached by them. A good example is found at Fairmount Park, Philadelphia, where the facilities of this kind are of an extensive character. The illustration presented herewith shows a pleasure ground station at the terminus of the Worcester and Southbridge (Mass.) Railway Company.

XII.

CAR HOUSES.

Statistical presentation.—The street railways of the country were required to report the number of car houses used by them, and the statistical results of the inquiry are given in Table 95. It appears from the table that 1,634 car houses were reported for the United States. These are widely distributed, but the states reporting the largest number are as follows: Massachusetts, 236; New York, 177; Pennsylvania, 173; Ohio, 138; Illinois, 96; New Jersey, 64; Michigan and Missouri, each 56; Connecticut, 55; California, 51; and Indiana, 50.

It will be noted that Massachusetts is far in the lead as to the number of car houses. Of the total number reported for that state, 115 are reported for the Old Colony Street Railway, the Boston and Northern Street Railway, and the Boston Elevated Railway. As these three companies report a total of 5,937 cars of all kinds, the car houses would seem to have an average capacity of 52 cars per car barn.

In New York state there were 14,040 cars accommodated in 177 barns, giving an average of 79 per car barn. This average, however, is brought up by the influence of such unusual figures as those of the Interurban (or Metropolitan) Street Railway Company of New York city, which accommodates 3,063 cars in 15 barns, an average of slightly over 204 cars per barn. This statement of itself gives an idea of the large amount of valuable property required in the heart of a great city merely for car storage, inspection, and repairs.

The state of Pennsylvania, with an aggregate of 7,058 cars and 173 barns, had an average of 41 cars per barn. Ohio, with 138 car barns and 4,395 cars of all kinds, had an average of about 32 cars per barn. Illinois, with an aggregate of 7,778 cars and 96 barns, had an average of 81 cars per barn; but these figures again are brought up by the totals for the two leading systems in Chicago, the Chicago City Railway and the Chicago Union Traction Company, which, with 22 barns, accommodated 4,818 cars, or 219 cars per barn.

Taking the country as a whole, it appears that with a total of 817 operating and 170 lessor companies, or a total of 987 companies, the average is not quite two car barns per company. These figures are worthy of detailed study from various standpoints, although they do not clearly show the burdens imposed upon the companies in making provision for sheltering their cars. Where a company has a large number of cars intended for winter use only, and a proportionately large number of open cars available only for summer use, it stands to reason that the car barn provision must be very much larger for the same aggregate of traffic than where a combination type of car is made to do duty the year around. Combination cars used throughout the year may be used up more quickly, though even this is not proved; but obviously less thought and money need be spent on the question of storing the cars when not in service.

Construction and equipment.—Great improvement has been made in recent years in the construction of car houses, which, until the advent of the trolley, were known as "car barns." In spite of the great attention given to fireproof construction of these buildings, the frequency of fires in such places has led insurance companies to increase the rates quite generally on such properties, and to be extremely careful in their inspection and rating. This in turn has led to further improvements, so that to-day many of the latest car houses compare favorably in fireproof quality with any other structures. If not properly built and properly looked after, a car house may become a dangerous risk, on account of the inflammable material usually gathered within its walls in the shape of cars, largely composed of wood, and large quantities of repair materials, paint, oil, varnish, etc. A very little indifference on the part of tired or careless men around the repair pits or stoves in a car house may result in a serious conflagration. Modern practice, therefore, in general requires that car houses shall be subdivided more or less so as to isolate and segregate a fire that may break out. Those of the most approved construction are one story in height, built of brick or stone, or both, with walls not less than 12 inches thick. Where there are two stories the lower one has walls 16 inches thick. The ground area of a separate section should not exceed 10,000 square feet. The fire walls throughout are built of brick, are without openings, and extend 3 feet above the roof. A heavy mill roof of 3-inch plank, covered with gravel, slate, or tin, is probably better than an iron truss roof with composite ironwork. Floors throughout are of brick, concrete, cinders, or dirt where the building is of one story, and a heavy mill construction is used for everything above the first floor where the building is of more than one story. The repair pits are of brick, with brick or concrete floors, each one extending under one track only, with steps of iron or other noncombustible material. These pits are located as near the rear end of the car house as possible, and are confined to one section of the house. The tracks in such a building run "clear" without a break, and the transfer tables are so arranged as not to interfere with the smooth and quick running of cars within the building. Inside protection is furnished by liberal standpipe water service, under heavy pressure, and provision is made for cutting off all power wiring from a point outside the house, leaving the trolley lines "dead" several feet from the front. There is also a liberal provision of fire pails and chemical extinguishers, as well as of fire hose. Oils, paints, and lamps are stored in a separate building, which is fireproof and ventilated. Few car houses answer to all these requirements, but there is a steady tendency to eliminate in every case the bad features and to adopt those which have been outlined above as standard, in compliance with the general requirements of the underwriters, as every deviation involves a higher insurance rate.

The variations in the details of car house construction are almost as numerous as the car houses themselves, and it would indeed be difficult to mention any two that are exactly alike. Some of the most interesting recent work is that connected with interurban roads, where the car house is also associated with other details of the system, and where special attention has, therefore, to be given to the insurance and to other features that are not considered in the building of a mere car shed.

Thus in Newark, Ohio, there is a large car house operated in connection with the interurban system, which includes Columbus, Newark, and Zanesville roads, and the Newark and Granville and other properties. This car house not only provides repair shops for the system, but it also receives current from the distant generating plant and serves as a substation for the rotary converters and alternating current transformers. The building is of brick, with sandstone trimmings, and is divided by a brick fire wall into two main parts, with an annex at one side containing offices, boiler room, lounging room for the men, and the substation. Each half of the main building is 60 feet from wall to wall, and contains working pits, machine room, repair shops, etc. There are 10 tracks with a capacity more than sufficient to accommodate all the cars on the system. The roof is built of steel trusses, covered with corrugated iron on purlines.

The Schenectady Railway Company has a very complete system of car houses and repair shops. It may be noted, by way of explanation, that the great amount of mechanical equipment required by many of the roads for the purpose of repairs has often led to the building of extensive and elaborate machine shops. Thus, for example, one of the buildings belonging to the Schenectady system, which was formerly used for the two purposes of a car house and repair shop, has been converted into a car house, while a new building has been put up for repair shop purposes exclusively. This new building is in three sections, with outside measurements of 201 by 210 feet. The first section contains an armature room, machine shop, and blacksmith shop, and adjoining the blacksmith shop an erecting room, with 300 feet of car pits. The middle section of the building has two floors, the front of the second floor being used for offices and the remainder for storerooms. The first floor of this section has a steam road switch running through it, and a teaming entrance in front provided with platform scales. In the rear is a large store yard for special work, rails, ties, and other heavy materials. The third section, which has three tracks, is divided in the middle from side to side, the front part being a machine shop and the rear a carpenter shop. Some idea of the equipment that goes into a modern street railway machine shop may be derived from the fact that in addition to the equipment already possessed, the company in equipping this building purchased two 15-ton hand operated cranes, a motor flat car equipped with an electrically driven crane of 5 tons capacity, a power rail bender, and a number of shapers, planers, boring mills, etc. The Schenectady company has also a well-equipped emergency house, with tower wagons which are provided with hose crossings, tools, and wire. This house is arranged after the manner of a fire engine house, and is connected with the fire department alarm system of Schenectady. The wagons respond to calls in all districts covered by its lighting and railway system.

Another interesting and up-to-date car house equipment is that of the Aurora, Elgin and Chicago Railway, an interurban system completed since the close of the census of 1902. The car house and repair shops of this road conform very closely to the standard, which has been explained in detail. The car house built in 1902 is in three sections, with two single tracks in each outside section for car storage, and in the middle section three tracks, two of which have repair pits beneath them. The floor between the tracks is much lower than usual, giving the men a space of from 20 to 24 inches in which to get at the sides of the trucks without lying down, as is necessary where the floor is built level with the rails. The repair pits are 4 feet 8 inches deep, giving plenty of room for work underneath the car. Across the central portion of the car house and spanning these three tracks is a 10-ton electric crane, which travels the entire length of the repair shop. This would be an abnormally heavy crane for a car house and shop of this capacity but for the fact that the interurban rolling stock of the system is very heavy, the cars being each equipped with four 125-horsepower motors. The width spanned by the crane is 40 feet. Each of the repair tracks accommodates one car. Though this building is spoken of as a car house, and answers that definition in almost every respect, it may be noted that the company follows in general the practice of steam railways of storing cars in the yards instead of in the house. There are yards in the front and rear of this car house and repair shop, and both yards join a main line of the track, the yard being thus a loop-off of the main line.

Lighting of buildings, shops, car houses, ways, etc.—In connection with the information furnished as to car houses, the street railway companies were asked to give statistics as to the lighting of their buildings, it being conjectured that in the aggregate a large amount of electric lighting would be shown. The companies naturally avail themselves of their own current, because they generate it in such quantities that the fraction added for lighting purposes would increase but imperceptibly the general cost of current production. Some car houses are illuminated by special low-voltage lighting dynamos, but most of them employ 500-volt current from the trolley wires. In these cases it is good practice to have the wires supported not less than 1 inch away from the walls of the building, ceiling, or floor, and to protect them carefully against accident or mechanical injury. In examining the mechanism on the underside of the cars, portable lights are often found necessary, especially in the car pits, but in every case where practicable preference is given to fixed lights. This is true also where gas is employed, all fixtures being rigid and the flames being kept at a considerable distance from any adjacent woodwork. According to the returns of the companies reporting electric lights employed in their buildings, shops, car houses, etc., 5,282 arc lamps and 235,955 incandescent lamps were in use for this purpose. The amount of lighting was usually about proportionate to the magnitude of the system reporting and to the number of the miles of track and cars owned. As will be seen from Table 95, New York reported 901 arc and 40,346 incandescent lamps; Massachusetts, 594 arc and 34,212 incandescent; Illinois, 369 arc and 22,388 incandescent; Ohio, 470 arc and 17,207 incandescent; Pennsylvania, 631 arc and 13,110 incandescent; New Jersey, 191 arc and 11,782 incandescent; Michigan, 107 arc and 10,406 incandescent; Indiana, 95 arc and 5,843 incandescent; and Missouri, 39 arc and 11,325 incandescent.

Some of the systems reporting have for their own use a larger amount of lighting than is furnished by many a good sized central station lighting plant for general urban purposes. The Boston Elevated Railway, for instance, reported 353 arc and 19,096 incandescent lamps; the Manhattan (Elevated) Railway, 200 arc and 8,000 incandescent; the Brooklyn Rapid Transit system, 150 arc and 9,000 incandescent; the Interurban (Metropolitan) Street Railway system, of New York city, 150 arc and 5,000 incandescent; and the Cleveland (Ohio) Electric Railway Company, 100 arc and 2,960 incandescent. In St. Louis, Mo., very few arc lamps were employed in car houses, shops, etc., but nearly 10,000 incandescent lamps were in use. In the same manner the Detroit United Railway Company did not report any arc lamps, but it had 1,800 incandescent lamps. On the other hand, the Pittsburg Railways

Company reported 220 arc and only 1,000 incandescent lamps. As a general rule, the roads in Philadelphia reported few of either kind of lamp. In Chicago, also, relatively little electric lighting was reported in spite of the extent of the electric systems there, the largest amount being reported by the Chicago Union Traction Company, with 100 arc and 1,500 incandescent lamps, and the Chicago City Railway, with 70 arc and 2,700 incandescent lamps. The Metropolitan West Side Elevated Railway of Chicago employed no arc lamps, but had 6,000 incandescent lamps in service. It is perhaps a fair inference that a large part of the lighting was for station purposes. The Rhode Island Suburban Railway Company, of Rhode Island, and the Union Railroad of Providence together reported 110 arc and 4,660 incandescent lamps.

XIII.

TELEPHONE SERVICE.

Two hundred and fifty-seven street railway companies reported exclusive telephone service, employed chiefly for car dispatching purposes. They used 5,868 miles of line. This does not include rented circuits or instruments or other apparatus leased from telephone companies. Detailed statistics with regard to the mileage of telephone lines will be found in Table 95. A considerable proportion of the mileage is found in the service of companies doing an interurban and rural district railway traffic. For example, the extensive system of the Union Traction Company of Indiana has 222 miles of telephone lines. In Massachusetts the Boston and Northern Street Railway Company reported 182 miles; the North Jersey Street Railway Company in New Jersey, which covers a large section of the state, reported 150 miles of telephone line; the Detroit United Railways Company of Michigan operated 150 miles; and in New York state the Hudson Valley Railway Company reported 137 miles.

As already noted the telephone is principally employed for car dispatching, especially on the interurban and suburban lines. On some of the longer and faster roads the automatic block signal system is in use; but the telephone has been found to lend itself to interurban railway work, on even the more important network of lines. The overhead line construction is particularly well adapted to the system, especially where center poles are used, as the telephone wires are thus brought near to the cars. But even with side poles there is little difficulty in making the connection, the only additional requirement being a longer cord between the telephone pole and the telephone. The telephone can be employed either by locating the telephone box or instruments within the car itself, or by attaching the box, under lock and key, to one of the poles along the route. An alternative method requires the car conductor to carry with him a portable telephone set, which he can plug in at any given point along the line where connections have been provided.

One method of using the system is to run two parallel telephone wires along the road with which the telephone is connected by means of double hooks, one above the other, or by a double-pronged hook introduced between the two telephone wires. The object of the two wires is to provide a metallic or two-wire circuit, which insures better service by cutting out the induction which would result from a one-line wire with ground return. This plan has been followed on the St. Louis, St. Charles and Western Railway, where two telephone wires are carried, one above the other, on insulators attached directly to the line pole, thus rendering the use of cross arms unnecessary. This telephone circuit runs the entire length of the road, with permanent connections to the line wires at the fixed telephone instruments in the offices or stations of the road. There are no telephone stations or connection boxes along the track of the route, but the telephone set is installed within the car. The telephone is used only when the car is stationary, and the connection with the line wires is effected by an ordinary fishing pole with telephone cord running along it. Two hooks are fastened to the extremity of this pole, the distance between them being a little less than that between the telephone line wires at their point of support. The upper hook has a spiral spring which allows considerable adjustment between it and the lower hook to insure good contact for both of them. The upper hook being caught into position, the weight of the pole causes the lower hook to rest securely in touch with the other wire.

The telephone system is largely used in connection with single track roads, especially at turn-outs. The practice in train dispatching on the interurban lines around Detroit illustrates the method. All the electric interurban railways radiating from Detroit operate under dispatchers' orders given by telephone. The methods used by the three different managements which operate these lines are very similar, and differ only in detail. In each case telephones are located in cabins or booths at sidings along the line, and no telephone instruments are carried on the cars. The orders are all received orally, and no written record is kept. The Detroit United Railway system operates all its interurban lines, except the Wyandotte division, from one dispatcher's office located at Royal Oak junction, 14 miles from Detroit, from which point the dispatcher has telephonic communication with the whole united interurban system. Orders are received at the telephone booths by the conductors and are repeated to the dispatcher. The motorman must be within hearing to hear the order repeated.

The telephone lines are mainly of iron wire. Those outside the city are run on brackets with "pony" insulators. To prevent inductive disturbances they are transposed every 10 poles, and in the case of high-tension alternating current lines, are transposed every 5 poles. The standard telephone equipment for the booths consists of a telephone instrument with an 1,800-ohm ringer, and a 5-bar magneto-generator which will ring through 60,000 ohms resistance. The instruments in each booth are connected with the line through a double-pole, single-throw switch. This switch is open when the telephone is not in use, in order that the line may not be rendered inefficient by having a large number of instruments bridged across it, thus increasing unnecessarily the resistance of the circuit. At the dispatcher's office there are switchboards in duplicate for the dispatcher, so that in case anything goes wrong with one board the other can be immediately switched in. There are four lines entering the dispatcher's office; connection with any one of these is established by simply throwing an operator's switch. The circuits are so arranged that communication can be had with many points on the system from two directions, and double-pole switches are placed at frequent intervals. In case a line is short circuited or grounded at a certain point, the switches on both sides of the trouble can be opened, and the work of dispatching can then be carried on without interruption. Within the city of Detroit telephone lines are frequently suspended from the electric railway span wires by means of porcelain insulators. This keeps the telephone wire in the middle of the street where it is free from interference by the trees.

One of the most interesting telephone systems recently put into operation in street railway service is that of the Manhattan Railway division of the Interborough Rapid Transit Company, of New York city. The exchange is located at Ninety-ninth street and Third avenue, in operating rooms built for the purpose above the car shops of the company. The main operating room contains the switchboard, the distributing frame, fuse rack, relay and coil racks, and the wire chief's desk. The board is of the "central energy" type with all the battery concentrated at the main office. The greatest distance from the central office to the instruments is about 8.5 miles. There are positions for 6 operators at the switchboard, each position being equipped with 15 pairs of intercommunicating plug circuits, consisting of double supervisory signals and combination ringing and listening cams. There is a testing section on the board, including a voltmeter and cord circuits for making ordinary line tests.

At the present time about 300 lines are in use, but the board as equipped would allow the operation of about 600 lines. The board is operated in the usual way with signal lamps, with additional bell signals for night service. The wire chief's desk is placed well in front of the switchboard and is so arranged that the attendant in charge can act both as monitor and as wire chief. Telephones are located in each passenger station and switch tower along the elevated tracks of the Manhattan Railway, as well as in all the offices, the power house, substations, and car shops.

Two styles of telephones are in use in the system. One of these is a wall type, which is employed in all the car shops, switch towers, inspection sheds, etc. The other style is a desk telephone, which is at the elbow of the ticket seller in his booth, and puts every station in direct touch with headquarters. All the outside wiring, connecting the exchange with the instruments, consists of lead covered cable, containing from 5 to 120 pairs of line. These cables are carried by a galvanized wire fastened to the elevated railroad structure with iron brackets or hangers. The force required for the system consists of the telephone engineer, 8 operators, and 5 repairmen. The operators work in 3 shifts, with 5 operators at the board in the busiest time of the day.

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CHAPTER IV.

INTERURBAN RAILWAY CONSTRUCTION AND EQUIPMENT.

In the Eastern states, until recently, the interurban roads have been usually an extension of some city system, owned and operated by it, and presenting few, if any, differences in the rolling stock and equipment within the city and outside. On the other hand, from the beginning of interurban railway construction in such states as Ohio, Indiana, and Michigan, as well as in those states farther west, cross country roads have often been planned and constructed to parallel and compete with steam railways, or to supply transportation to sections which the steam railways had not found it profitable to reach. It thus appears that, while many of the eastern interurban systems, which have now grown into networks of considerable magnitude, present close analogies to the street railway systems, of which they still remain a part; not a few of the western roads are to all intents and purposes steam railways, with the substitution of the self-contained electric car for the steam locomotive.

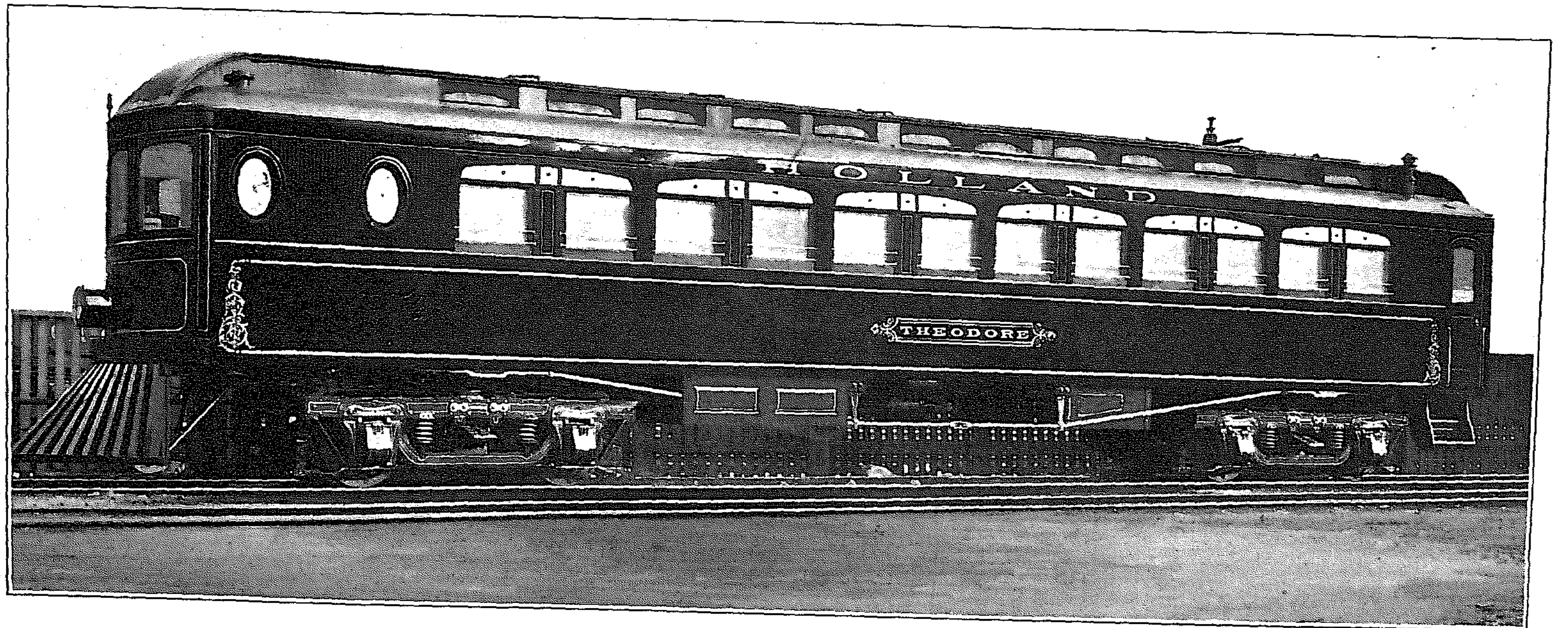
Where the interurban road is an outgrowth of the street railway system the tracks and roadbed are usually of the character to be found in semicity districts. In some instances, as, for example, in the case of the road between Albany and Schenectady, N. Y., a distance of about 18 miles, the construction of the road has helped the building in rural regions of roadways of a superior construction, such as would probably not have been found there but for the trolley.

In the Central West at least 75 per cent of the interurban roads are located on private rights of way, which usually follow the line of the public highway. The private right of way is from 30 to 40 feet wide for single track roads, on which a standard roadbed is laid with 70 to 80 pound rails and with No. 0000 copper bonds at each joint in the rail. As a general thing the electric roads have been less careful than the steam roads to avoid grades and curves. The engineers have often relied upon the high-tractive ability of the electric motor car, as compared with the locomotive, for work on steep grades. The bridge construction along such roads, however, is very often of a superior character, consisting of steel girder construction and comparing favorably with steam railway practices.

In the case of single track interurban roads, bracket construction is generally used for the overhead wires, with poles about 35 feet high, set from 90 to 100 feet apart. The bracket arm has flexible suspension for the entire length of the trolley wire. Two trolley wires are usually employed as a means of avoiding overhead frogs at turn-outs, which makes possible the maintenance of high speed and avoids interruption of the service in case of the breaking of one of the wires. The trolley poles also carry the high-tension lines transmitting the alternating current, which is lowered in pressure and converted into direct current at the frequent substations, for use on the service wires and cars. Copper wire is largely in use for this current and for the direct current feeders, but already about 20 per cent of such circuits are composed of aluminum wire, which is being experimented with. The three high-tension wires constituting the three sides of the three-phase circuits running from the generator at the power plant to the transformer at the substation are usually carried at the tops of the poles in the form of an equilateral triangle, with the wires 8 inches apart. In this way pressures as high as 40,000 volts are successfully sustained. The circuits are carried on glass or porcelain insulators, and are protected by lightning arresters against storms which might otherwise do damage to line and cars.

Third-rail traction.—A considerable number of interurban roads have adopted the third-rail system. One of the most noteworthy of these, technically, is that extending from Albany to Hudson, N. Y., which has been in operation for two or three years, and which has an unprotected third rail.

A notable system with protected third rail is that extending from Wilkesbarre to Hazelton, Pa. The contact rail, which is the main feature of the system, so far as this section of the report is concerned, is protected from sleet and snow by means of a hood, made of 2 by 6 inch pine plank held directly over the rail, supported by oak posts spaced every 8 feet. Both guard and rail are carried by unglazed vitrified clay insulators, spaced every 10 feet on the ties. Owing to the protection over the third rail the contact shoes or plows are in the form of a tongue or thick plate extending outward horizontally from the car truck, so pivoted and ratcheted that its adjustment to the rail can be changed readily. There is also a switch governing the connections between the third-rail shoe and the overhead trolley, which is employed for use within city limits. This railway is 26.2 miles in length and the journey by steam road between these two cities has hitherto occupied two hours. At the same average speed the Wilkesbarre and Hazelton



EXTERIOR OF FIRST AMERICAN TROLLEY SLEEPING CAR.

road can carry passengers in seventy minutes or less between the same points. The speed ordinances governing the movement of the cars in the streets of the respective cities leave only forty minutes out of sixty or seventy in which to cover the distance over the private right of way. There is a difference of 1,200 feet in the altitude of the terminal points and the right of way, 60 feet wide, is so laid out that throughout the entire line there is not a grade exceeding 3 per cent and only one curve of 18°. The grade thus established necessitated some heavy fills and deep rock cuts and a tunnel 2,600 feet long through the Penobscot mountain.

Another interesting third-rail system is that of the Jackson and Battle Creek Traction Company, connecting the cities of Jackson and Battle Creek, in Michigan, about 45 miles apart. This road is single track and built on private right of way. It has a third-rail contact, with the contact rail outside the track rails. The head of the contact rail is 6 inches above the track rails, and is supported on reconstructed granite insulators without iron top or base, placed every 10 feet. At road and farm crossings the third rail is broken and the circuit is continued under the track with lead covered and paper insulated cables. At these points the third rail is provided with oak inclines or tips.

A third-rail system has been built on the Pacific coast between San Francisco and San Rafael, a distance of 13.69 miles, by the North Shore Railroad Company, which had previously operated by steam. For the third or contact rail, which is placed outside the regular track, 60-pound rails are used over about half of the line in 30-foot lengths, and 56-pound rails over the rest. The ends of the rail at crossings are tipped or fitted with an approach block in the usual manner. The rail is mounted on block insulators fastened to the ends of every fifth tie, so as to give the insulators 10 feet between centers. Wooden insulators have been used for this purpose, and this cheaper construction appears to have been justified by the successful operation of the road in all kinds of weather, although this region is free from snow and sleet. The material used for the insulator is California redwood covered with a coat of asphaltic paint. The top of the contact rail is 6 inches above the top of the running rail, and the center of the rail is 27 inches outside of the gauge line of track. Where the roadbed will permit, the contact rails are supported on beams 4 by 6 inches laid across two ties, and fastened to the latter by wooden treenails. Where an earth support is used, the contact rails are supported independently of the track by means of strips 2 by 6 inches and 3 inches long treenailed to the tops of stout posts driven into the ground to such a depth as to give the correct elevation to the contact rail. In the yards at Sausalito and San Rafael the contact rail has been equipped with a guard or hood, the device employed being similar to that used on the Wilkesbarre and Hazelton road. At station platforms the contact rail is still more carefully guarded. At crossings, stations, and other exposed points warning signs have been placed. The total mileage of electrically operated track on this system is 13.69 miles.

Passenger cars.—The rolling stock of interurban roads is very often quite similar to that employed on urban systems, but important modifications have in many cases been made to meet local requirements. A fast schedule is a desirable feature of strictly interurban service, and this is determined by the character of the rolling stock and roadbed. Yet the maximum speed becomes important only when the length of the run between stops exceeds 1 or 2 miles. In the usual mixed city and interurban service stops will vary from ten to the mile in the city to one in 5 miles or even less in the interurban portion. They average four stops per mile in the city, two in the suburbs, and one to one and one-half in every 2 miles of rural track. Hence the power to secure proper acceleration is of considerable importance in maintaining a fast schedule, and attention is given to this point in the motor equipment of the car.

All the interurban cars are of the double-truck type, and a great many of them are equipped with four motors, one on each axle. If the grade exceeds 5 per cent and the rate of acceleration exceeds 1.75 miles per hour per second, four motors per car are found essential to a reliable service. Even where other conditions would permit the use of two motors the dimensions required for the necessary horsepower may be such as to exceed the allowable space, in which case four motors of smaller build but of the same capacity are used. A 6-foot wheel base has been generally adopted for bogie trucks, which, with a 6½-inch axle and a 12-inch bolster, leaves little space for the motor. The wheel diameter is limited in many cases to 33 inches by the required height of the car body. There is a tendency to the use of longer wheel bases, owing to the high speed at which the interurban roads have lately been operating.

The average length of the standard interurban car today is about 50 feet, with a total weight, when equipped, of 25 tons, and with four motors of 50 horsepower, one upon each axle of the double trucks. The air brakes are usually motor driven, but one or two of the lines employ storage air. Many of the cars provide both baggage and passenger accommodations, the baggage compartment being used also as a smoking compartment. All of them are lighted with electricity. Many are heated by hot water, this proving more economical and efficient than direct electrical heating under the conditions involved. In Michigan some of the cars are over 60 feet in length, with high-backed upholstered seats, M. C. B. trucks, and steel tired wheels. Some of the cars on the Columbus, Delaware and Marion (Ohio) Railway Company's line are 66.3 feet over all, being at least 5 feet longer than any other interurban cars built, so far as known. On the same line there are also some handsome 50-foot cars divided into two compartments, with a seating capacity of 52 passengers. The cost of the car, finished in solid mahogany with extra bronze trimmings and elaborate electroliers, was about $11,000.

A number of the cars on interurban roads are of the semiconvertible type already referred to in another chapter, while open cars are also in use to some extent. On high-speed roads the ordinary type of open car with outer running board has obvious objections. Those built for the Northern Texas Traction Company have a center aisle with end entrances.

One of the most interesting developments in the rolling stock of these interurban lines has been the construction and equipment of two sleeping cars for use on the Ohio and Indiana long interurban lines. The car is similar in outward appearance to an ordinary parlor or sleeping car, and is mounted on two trucks, each of which is arranged to carry two 150-horsepower motors, giving a total of four motors of 600-horsepower capacity for the car. The interior arrangement is different from that of the ordinary sleeping car. The upper berth is folded up during the day, and the lower berth consists of two revolving chairs, which are swung together at night, the cushions for the berth being obtained from the bottoms and backs of the chairs. The car has a second or false floor built on top of the regular floor, and the partitions all slide down between the double floors in the daytime, working on the same principle as a roller top desk. The berths are 27 inches wide, which leaves 15 inches between the sides of the berth and the partitions of the compartment. The coach is fitted with the regular motorman's cab, controller apparatus, headlight, cowcatcher, etc.

Freight and express service.—For a long time it has been the practice to carry mail matter on street cars. This began with the granting of free transportation to mail carriers with their baggage, and has developed gradually into a service which comprises completely equipped mail cars in which letters and newspapers can be sorted and disposed of. It is a frequent practice to furnish street cars with boxes into which mail matter can be dropped along the route traversed by the car, the mail being collected from the car at the points most convenient to the general post office.

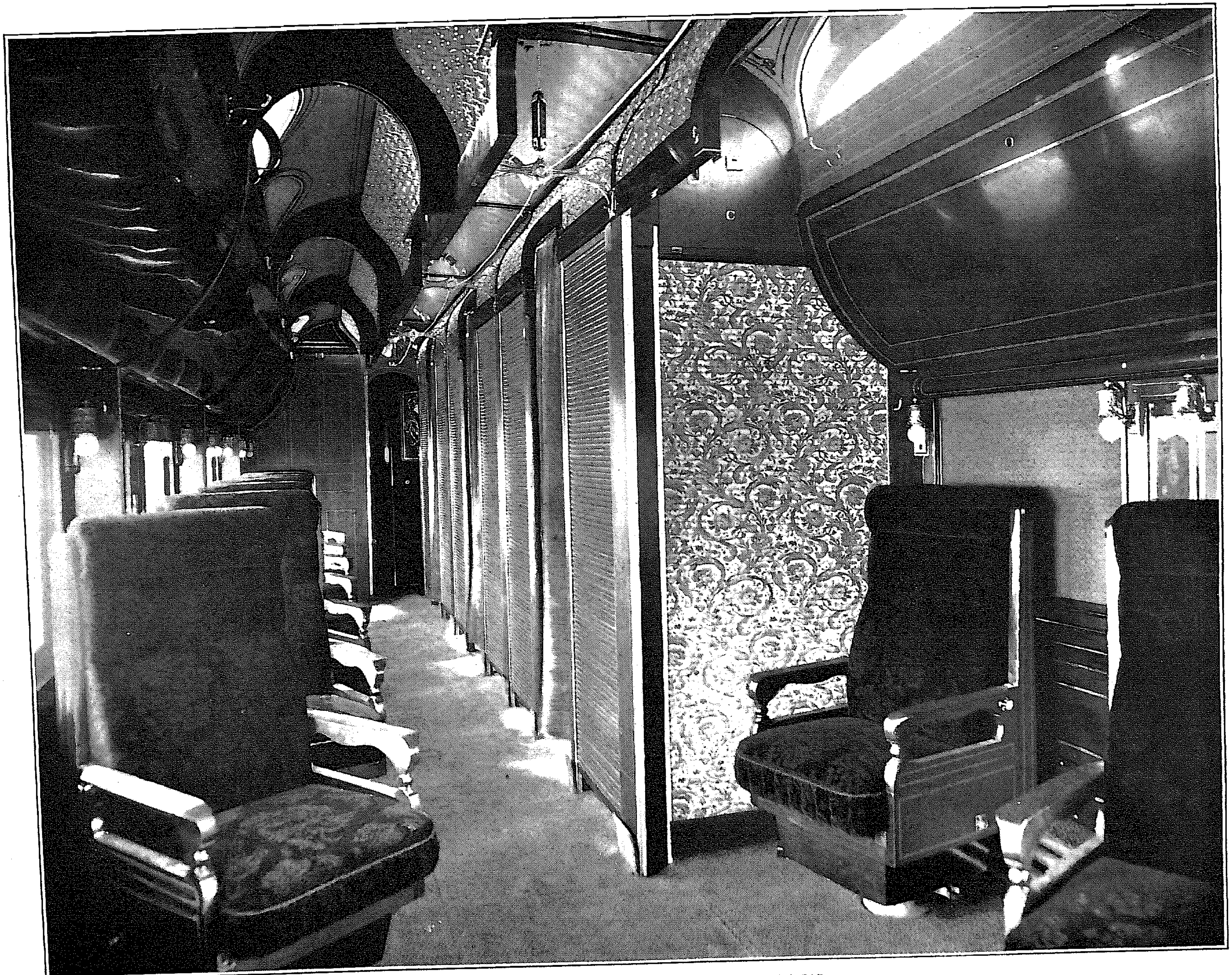
The handling of baggage and freight on street railway lines had a slower development, and is still in its experimental stage. In New York city an express transportation company operates in connection with the Metropolitan Street Railway Company and utilizes several express street cars, which run between designated points at certain hours of the day solely for the purpose of transferring express, baggage, and packages in bulk.

Some of the street railway companies have gone more thoroughly into the heavy freight business, and have provided themselves with rolling stock and freight houses.

But the most extensive development of freight and express business has taken place on the interurban lines. An illustration of this development is found in the case of the various interurban lines entering Toledo, Ohio, over the tracks of the Toledo Railways and Light Company, with which they have traffic arrangements. The freight cars of these lines run alongside a regular freight house, with a large unloading platform. Six cars can be accommodated at the same time, and there is ample space for drays to load and unload. Freight cars are run at such hours of the day and night as interfere least with the regular schedule of passenger cars. The freight depot is owned by the city company, each interurban company paying a certain rental. The schedules of the several roads using this terminal are so arranged that the freight cars do not reach the station at the same time, and the work is equalized throughout the day. The Lake Shore Electric Railway operates three freight runs or three cars a day each way. It sends out a special meat car every day from Toledo. The Toledo and Monroe and the Toledo and Maumee Valley railways have each two cars each way. The Toledo and Western Railway has two runs out of the station each day. It brings a special milk car into the city every morning. Milk is handled by all the roads named at a straight rate of 1½ cents a gallon for any distance, and milk tickets are sold by the general officers and agents of each company. Special carload lots are handled at special rates, the Toledo station agent being authorized to give carload rates over any of the roads. The minimum charge for any article is 25 cents. The freight station is managed by a committee composed of the general managers of the companies interested; but the business of each road is conducted separately.

Many of the cars on these roads are ordinary freight cars with brake equipment, etc., similar to that on steam railways. A great many of the interurban cars, however, have freight or baggage compartments in the passenger cars. The Steubenville Traction and Light Company handles all its freight in combination cars. The rates are not so high as the express rates, but slightly in advance of the steam railroad freight charges. Out of a total car length over the bumpers of 40 feet 8 inches, the baggage section occupies 11 feet 6 inches, giving space for a large quantity of miscellaneous freight and express.

Many of these roads have developed a regular system of accounting for freight and express service, the system being similar to that followed by the express companies of this country. The Dayton and Troy (Ohio) Electric Railway has its own wagons for express service in the larger stations, but in smaller places it pays 20 per cent of the charges for delivery to the parcel delivery wagons. It has through billing arrangements with the Southern Ohio Express Company, which operates on the Southern Ohio Traction Company's cars, its express rates being considerably under those of the old express companies.



INTERIOR VIEW OF FIRST AMERICAN TROLLEY SLEEPING CAR.

This company has 55-foot freight cars, which make two round trips every day between Piqua and Dayton. The company issues a freight classification, identical with the regular railroad classification, upon which rates are based. Through billing of freight has been arranged for between the lines of several of the traction companies which enter Dayton by a division of the charges and a sharing of the expense.

The Mahoning Valley (Ohio and Pennsylvania) Railway Company operates two closed cars, built especially for freight and express service. There are 3 men on each car—the conductor, the motorman, and a laborer. Freight depots have been located in each city and village through which the line operates, although not all were constructed for this purpose. At Niles, Ohio, a depot has been built especially for freight business in connection with the company's power house; at Girard, Struthers, Lowellville, Ohio, and Newcastle, Pa., the company has buildings of its own; at Youngstown, Ohio, and at Edenburg, Pa., there are freight rooms in connection with the stations. The company does not use combination cars. It is the policy of the management to keep the passenger traffic entirely distinct from the freight business.

The package freight business of the Cincinnati, Dayton and Toledo Traction Company, formerly the Southern Ohio Traction Company, is conducted by the Southern Express Company. When the Southern Ohio properties were first consolidated the express business was placed in the hands of the Wells-Fargo Express Company under a contract similar to those in force on steam roads. The net returns to the traction company were not satisfactory, however, and the company decided to conduct the business itself. The Southern Ohio Express Company is a distinct organization, incorporated with a nominal capital stock of $2,500. The traction company furnishes the cars, crews, and power and receives 10 cents per car mile for the mileage of the freight cars. The express company operates two 35-foot freight cars between Cincinnati and Dayton, making two trips each way per day. At the beginning it purchased 30 first-class wagons and teams, sending out numerous solicitors and establishing stations in the leading towns in the territory it intended to occupy. Delivery wagons are maintained in all the leading towns, and in Cincinnati and Dayton the wagons have regular routes, making four trips per day to over 1,500 leading business houses. The company uses the traction company's passenger and terminal stations in Cincinnati, Hamilton, Middletown, Franklin, Miamisburg, and Dayton, paying half the expenses of the maintenance of the station and the salaries of its own agents. The operating expenses of the express company amount to about 75 per cent of the gross receipts. For a time the net loss was large, but for the year 1902–3 it was estimated that the net profits would be about $10,000.

CHAPTER V.

POWER HOUSES, EQUIPMENT, AND OUTPUT.

I.

POWER PLANT AND GENERATING EQUIPMENT.

The data relating to power plant and electric generating equipment of street railway companies are shown in Table 96. The use of electricity or other mechanical motive power was reported by 764 companies, which returned a statement of 805 power houses, not including substations and companies that purchased their motive power.

As steam was reported by 540 companies as the primary motive power for generating their electric current, it would appear that these companies in some instances embrace a number of subsidiary companies, thus furnishing current for their whole network from plants of a sufficient capacity to care for the necessities of more than one road. The 2,336 steam engines, which are classified in the table according to horsepower capacity, had an average of 556 horsepower per engine. The 1,589 engines, with a capacity of 500 horsepower or under, had a total capacity of 421,051 horsepower, an average of 265 horsepower per engine. The 430 engines having a capacity of more than 500 but less than 1,000 horsepower had a total capacity of 297,257 horsepower, an average of 691 horsepower per engine. The 317 engines of 1,000 horsepower and over had a total capacity of 579,825 horsepower, an average of 1,829 horsepower per engine.

There were 37 companies that reported the direct use of waterpower in their own plants for current generation and that did not sell any such power in the form of hydraulic service or electric current. These companies used 159 water wheels or turbines, with a total of 49,153 horsepower, an average of slightly over 300 horsepower per wheel. There were 129 water wheels of 500 horsepower or under; 12 of more than 500 but less than 1,000 horsepower; and 18 of 1,000 but less than 2,000 horsepower. Of the total horsepower thus reported, 34,215, or 69.6 per cent, was reported by 16 companies in the states of California, Georgia, Maine, Minnesota, and New York. The largest plant of this nature was shown for the Twin City Rapid Transit Company, of Minneapolis, Minn., which reported the use of 12 water wheels, 10 of which were of 1,000 horsepower each. It should be borne in mind, however, that other than that included in the table, waterpower is extensively used for the operation of street railway companies. A notable case is that found at Niagara Falls, which may be taken as typical, and which not only generates current directly for the local street railway network at the Falls, but which also transmits an immense amount of power some 20 miles to Buffalo, where it is manipulated and employed on a large scale for the propulsion of the cars of the Buffalo systems, as well as the cars of the interurban system between the two points. Detailed statistics of water wheels will be found in Supplementary Table 3, which also presents the details for the gas engines employed in the main generating plants.

It appears that 15 gas engines, of a total of 1,925 horsepower, were employed. Three of these, with a total of 1,000 horsepower, were located in the state of Pennsylvania, and 5, of a total of 400 horsepower, in Illinois. These two states alone account for nearly 75 per cent of the capacity reported. The power plant statistics in Table 96 include also 301 auxiliary steam engines, of a total capacity of 10,074 horsepower, which were used by 84 companies for miscellaneous purposes, such as driving pumps, etc.

The power plants referred to in Table 96 reported a total of 3,853 boilers, with an indicated capacity of 893,205 horsepower, the average capacity per boiler being 232 horsepower. In a general way the approved practice is to have a boiler capacity larger than the engine capacity and an engine capacity larger than the generator capacity, thus providing a liberal factor or percentage of safety over unavoidable losses. The figures in Table 96 would indicate an apparent departure from this practice, but the departure is more apparent than real. As a matter of fact, the boiler capacity would usually be found quite adequate for the work it is required to do. Many power houses have dynamo and engine capacity in duplicate or in reserve to provide against a possible breakdown of any unit, or for changing the load from one set of apparatus to another, according to the demands at different hours of the day, although the same boilers remain in active service all the time.

The statistics for the number and horsepower of dynamos driven by steam engines, gas engines, and water wheels, respectively, are given in Table 96. The table shows a total of 3,302 dynamos of all kinds, with a total capacity of 1,204,238 horsepower; in round numbers, about 900,000 kilowatts. The 2,861 dynamos of the direct current type had a total capacity of 972,314 horsepower, and the 441 alternating current dynamos a total capacity of 231,924 horsepower. It appears, therefore, that the direct current apparatus furnished nearly 81 per cent of the total capacity. Of the direct current dynamos, 2,324 had a capacity of 500 horsepower or less, with a total of 422,924 horsepower; 328, more than 500 but less than 1,000 horsepower capacity, with a total of 218,934 horsepower; and 209 had a capacity of 1,000 horsepower and over, with a total capacity of 330,456 horsepower. The use of small machines evidently predominates, as more than three-fourths of all the machinery was rated at 500 horsepower or under, and the capacity of such dynamos was 43.5 per cent of the total for direct current. Supplementary Table 4, which supplements Table 96, in regard to the distribution of alternating current dynamos, shows that this form of dynamo was employed by 163 companies. Of this number 128 reported that they also generated current for sale for light and power, thus indicating the use of these generators on a wide range of service, quite aside from and additional to that in the street railway field. The 441 alternating current dynamos had a total capacity of 231,924 horsepower, an average of 526 horsepower per dynamo. Three hundred and twenty-nine of these machines were of 500 horsepower or under, with a total capacity of 61,935 horsepower; 54 were of more than 500 but less than 1,000 horsepower, with a total of 36,418 horsepower; and 58 were of 1,000 horsepower and over, with a total capacity of 133,571 horsepower. It appears, therefore, that the alternating current dynamo reversed the conditions in regard to direct current, and that the 58 dynamos of the larger size, or only 13 per cent of the total number, have 57.6 per cent of the total capacity.

Location of power house.—The electric railway power house and its equipment and the methods adopted for delivering current to the line, are among the most important subjects embraced within this report. Although the conditions of operation and the nature of the apparatus employed have changed in a most radical and revolutionary way since the first trolley car went into successful operation, certain fundamental principles still, and will probably always, apply to the location of the power plant itself, although it is by no means sure that the substations will remain as they are, either as to location or as to equipment, or even as a continuing necessity.

The considerations governing the location of the central power house are primarily those connected with the supply of fuel or juxtaposition to the waterpower by which the generators are to be driven, and next to these considerations may be said to come the supply of water for the boilers and the disposal of ashes. Hence, in a great many places, it has been found desirable to place the power plant near the railroad tracks over which its coal supply must be transported. In towns of smaller size and on interurban roads the governing consideration is not centralization, but is to be looked for rather in convenience of access to the coal or water supply. The location of the power house has, moreover, been rendered of less vital importance than formerly by the general adoption of the plan of having substations, a practice which naturally makes for flexibility. The substation itself is the outgrowth of the widespread use of alternating current machinery instead of direct current generation.

The well-established limits to the economic distribution of direct current at the ordinary voltages for street railway work—say, between 450 and 550 volts at the motors—do not exceed 10 miles, although longer distances have been covered. A great many electric railway systems far exceed such a length either in total mileage of track within a limited area or in the continuous stretch of a line in some given direction; but if the power plant be direct current, and be located midway of the line of road 16 to 20 miles long, it is advantageously disposed with regard to its work, and can feed current economically to cars even at the two termini. When, however, roads are from 50 to 100 miles in length, the substation becomes a necessity, if the current is to be distributed from one central power house. The high-pressure alternating current has been found in practice, during the past ten years, to be equally desirable for current distribution in cities where every inch of traction is well within the limit at which direct current could be furnished economically to the cars from a central power house. The principal reason for this is that the use of the alternating current enables the power houses to be centralized and reduced in number. Indeed many engineers believe that with alternating current motors on the cars substations will disappear, or at least will be so modified as to their functions that the location of the power house may have to be determined upon other grounds and arguments than have heretofore applied. If this belief is well founded, the practice of using substations will have proved a short lived one. But it may be pointed out that the literature of the industry ten years ago is virtually bare of reference to alternating current supplied to substations. For a time, and even at the period in the art under discussion, boosters for maintaining voltage at remote points on the system offered a temporary solution of the difficulties encountered in direct current supply. The recent advent of alternating current, however, has so changed the outlook and the conditions that the uneconomical booster is no longer considered as a serious factor. In the earlier days the question of determining the best location of the station might be governed by the fact that, in order to attain cheap fuel or a cheap water supply, the gain in this direction might be offset by the increased investment in feeder construction. Here again resort to the alternating current has modified the principles which governed within the decade.

A few figures compiled by Mr. A. B. Herrick, bearing upon these points, may be cited as of general interest:

Take, for example, a 15-mile stretch of road with cars uniformly placed, requiring 20 amperes per mile average and 40 amperes per mile maximum, and assume 20 per cent drop in voltage on 7½ miles of road. With the station centrally located the copper will cost about $20,000. If the station is 2 miles from the center of distribution the installation cost for copper will be increased $6,700. Property in the central location would, therefore, be worth this much more to the railway company, as better distribution could be obtained from a station on that site.

Where the coal can be delivered directly from the cars to the coal bins of the station the cost for handling is at the lowest. Where there is any rehandling the price depends upon the distance traversed. To load and move 1 ton 1 mile or less costs about 25 cents per ton; 1½ miles, 30 cents; 2 miles, 32 cents. These figures are taken from average prices paid for hauling over a variety of roads. A station with the capacity mentioned above would require, on an average, about 11 tons of coal per day. If hauled 1 mile this would cost per year, with shrinkage in coal weight due to moving, about $1,000, or 6 per cent on an investment of $16,666.

The value of condensation in a street railway plant of the size cited above can be roughly estimated at 18 per cent saving in coal. At $2.80 per ton this would be $2,023 per year, or 6 per cent on an investment of $33,700. This station would take about 700,000 cubic feet of water per annum for boiler use. If the water had to be bought at, say, $1 per 1,000 cubic feet a site would be worth $11,600 more where free water could be obtained.

Construction of power houses.—The electric railway power houses enumerated in this report are almost universally built of brick with stone trimmings, and are usually of a most substantial character. They are sometimes quite ornate in appearance. Of late steel framework has been largely resorted to in their construction. It is a common and advantageous plan to divide the building into two main portions, one occupied by the boilers, the other by the engine or dynamo. In some cases the power plant is associated with the car barns and even with the general offices of the company. In some plants the building, instead of being laid out on one floor at the street level, is two or three stories in height, with the various steam and electrical departments imposed one upon another. The determining consideration in this matter of height is usually the cost of real estate.

The building requirements laid down by insurance companies for rating risks on electric light and power stations indicate, in detail, what would be generally regarded as the best present day practice in such construction. The regulations and restrictions embody the following features:

Walls: Brick or stone, at least 8 inches in thickness for a one-story station, and 4 inches to be added for each additional story; or iron, to extend at least 3 feet above roof. Height: One story, without space below. Area: Not over 5,000 square feet of ground between standard fire walls. Roof: Metal, with metal trusses and supports. Floor: Brick, cement, stone, or earth. Wooden platforms may be used about machines. Cornice: Brick, stone, or metal. Eaves: Not less than 15 feet from ground. Finish: No combustible finish or finish leaving concealed spaces. Division walls, if any, to be of brick or stone, with standard fire doors or shutters. Partitions about offices, storerooms, or elsewhere to be of noncombustible material. Boiler, except in standard station, to be outside or cut off by standard fire wall, with standard fire doors and shutters. Roof of boiler house to have proper ventilator. Stack: Brick, or if iron, to be outside and on brick foundation. Wire tower, if any, to be brick or stone, with same kind of roof as station proper. Stairs, if any, to be properly inclosed when deemed necessary. Elevators, if any, to be in brick tower, or with self-closing hatches. Heating to be by steam, hot water, or hot air by blower system; piping for same to be free from woodwork and supported by iron hangers. Stoves may be used in office only. Lighting to be by gas, with brackets so arranged as not to allow flame to come in contact with woodwork; or by electricity, with wiring in accordance with rules. Occupancy to be only for legitimate uses of the station itself. Exposure: Must be unexposed to other hazards within 50 feet; or, if exposed, to have approved fire walls on exposed sides.

Equipment of power houses.—At the beginning of the ten-year period which closed with the year of the special investigation, steam generating plants were usually equipped with sectional tubular boilers similar to those in most modern plants, and many other features of construction and equipment were not greatly dissimilar to those of to-day. The great power plant of 1902 differs most strikingly from the older plant in its more general use of automatic machinery of all kinds for bringing coal to the boiler fronts, for stoking the fuel upon the grates, and for disposing of ashes. The generating plants in 1892 usually consisted of a number of small units leather-belted directly to the steam engines, sometimes even with the intervention of countershafting. Direct connected engines and dynamos were rare. Most of the engines at that time, therefore, were of high speed, and the dynamos or electric generators were of the bipolar type. The engines were frequently simple in type, and even when compounded were often run noncondensing. The bipolar generators, though wound for the higher voltages—e. g., 500 volts—even then becoming the standard on street railways, were of the general type designed for electric lighting, and were not particularly well adapted for the purposes intended. The water wheels now in use in electric railway power houses do not differ greatly from those of 1892, except that it has been found necessary to adapt them to generating plants of the long-distance power-transmission type. In 1892, however, the heads under which the water wheels operated were far less efficient than those of 1902, and the requirements were in every respect less exacting, the units, moreover, being much smaller.

In the modern plant much care and thought are given to the classifications and specifications applying to the equipment, especially the huge generators and steam engines, or turbines. The engine and generator specifications, for example, must be in harmony so far as capacity, speed, and regulation are concerned. It is the general practice of manufacturers of generating dynamos to give their machinery a nominal rating, which allows for 25 per cent, 50 per cent, or even 75 per cent overload for certain periods of time ranging from ten minutes up to two hours or longer. The engine built to drive direct or continuous current generated in this class of work is designed for rapid changes of speed and output, for certain changes in the load and for close regulation. What would be considered ideal regulation in a direct current plant, however, would hardly be satisfactory with alternating current generators. There is no great difficulty in running two or more direct current generators together on the same circuit, and in dividing the load so that each does its share of work; but in running alternating current generators, particularly at slow or medium speeds, the problem is different, and calls for other conditions of design.

The engineering societies of the country, such as the American Institute of Electrical Engineers, and the American Society of Mechanical Engineers, have formulated general rules bearing upon these points, and established certain standards for direct connected generating sets of machinery. As to the general practice throughout the country at the time of this report, some interesting variations in practice may be noted.

Direct current generators are still retained in a few of the larger cities, such as Boston, Mass., where the Boston Elevated Railway Company, operating both surface and elevated lines, has continued to use direct current and has erected a number of small stations instead of concentrating its power in one or two large ones. Thus the company reported 8 power plants in 1902. It is interesting to note that while the original power plant of this system had a few years ago 36 small generators, each one of only 50-kilowatt capacity, the company now has 5 generators, each of 2,700-kilowatt capacity. About 20 per cent of the capacity of the company's stations is used for supplying the elevated lines and 80 per cent for the surface lines. In Chicago, Ill., also, the street railway companies were still supplying their lines from direct current power plants, some of the apparatus belonging to the earlier stages of the art, with simple engines and rope driven generators, but the new work contemplated brings the engineering in the street railway field in that city up to date. In Cleveland, Ohio, Indianapolis, Ind., and to a large extent Milwaukee, Wis., direct current generation continues to be the standard usage.

In Minneapolis and St. Paul, Minn., the Twin City Rapid Transit Company has had the advantage of a waterpower of about 7,500-kilowatt capacity, but the growth of business has necessitated the addition of a steam plant whose ultimate capacity will be 21,000 kilowatts. The system is alternating current, 3-phase, the waterpower plant being about midway between the two cities, and the station voltage is 3,450-volts 3-phase, at which pressure current is transmitted to the substation in Minneapolis. In transmission to St. Paul the voltage is raised to 13,000. At both points the current is, of course, "stepped down" and converted in the usual way for use on the cars, the substations having storage batteries. At Philadelphia, Pa., the three principal power houses have been direct current, but a change is being made to 3-phase alternating. The same is true of Pittsburg, where the Pittsburg Railways Company has heretofore operated no fewer than eight direct-current stations. In San Francisco the United Railroads have had five direct current power plants in operation, but have been making a change to alternating current for generating and transmission. St. Louis affords, probably, the most important example in this country of direct current street railway power plants, with its enlarged station at Park and Vandeventer avenues, having an output of 30,000 amperes. The alternating current has now, however, penetrated into this territory for use in the outlying part of the company's system.

It will be seen from the foregoing facts that the direct current plant is still regarded as modern, economical, and efficient, and is largely in use, though not what the French would call the "dernier cri."

In August, 1903, at the time when the compilation of the statistics in this volume was approaching its conclusion, alternating current stations for supplying a large proportion of the load were in use or under construction in New York, Kansas City, Baltimore, and San Francisco. Combination direct and alternating current plants, where the direct current is used to supply what may be termed the inner circle, while the outlying regions are operated with the aid of the transformed and converted alternating current, were in use in Brooklyn, Denver, Milwaukee, Philadelphia, Pittsburg, and St. Louis. The large use of waterpower at Minneapolis and St. Paul in connection with alternating current has already been noted. In Buffalo the power plants for street railway work consisted largely of substations for that part of the current generated at Niagara and transmitted by 3-phase lines, partly overhead and partly underground.

It has been stated by many authorities that there is considerable difference between the lay-out, or plan, of a large alternating current station, in which nearly all the power for supplying the system is concentrated, and the plan of smaller direct current plants. This is due partly to size and partly to the fact that the concentration of an immense amount of generating apparatus under one roof makes interruption of service much more possible and serious than where a number of scattered stations feeding into the common network are in operation.

The plan of isolating one section of a station from another is now being very thoroughly carried out in large plants. For example, in the large alternating current stations special provision is made for the isolation from each other of high-tension bus-bars in brick and stone insulating cells, and for the segregation of the generators into individual groups, so that trouble with one group can not affect the others. As interruptions are also to be feared from the steam piping and boiler room, the prevalent practice of connecting large generators, engines, and boilers, in parallel permanently, on the same bus-bars and steam pipe lines, has been abandoned in the best modern power houses. It is evident that, with the introduction of units of 5,000 kilowatts and upward, the permanent united operation of the entire station is not necessary, as it is with the smaller units. A study of the latest designs shows that in stations with such heavy units, each unit with its boilers becomes a section of the station by itself; capable of being operated in parallel with other units, but only through the medium of steam piping and electrical connections, which can be quickly cut apart. In steam piping, companies now use quick-acting electrically-operated valves, thus avoiding the danger heretofore always present in the older systems, due to the fact that essential valves could not always be reached in case of accident.

Another feature which has required careful attention on account of mining strikes, has been the storing of coal. It is most essential that there should be adequate storage room for emergency supplies, and, moreover, engineers have been obliged to devote a great deal of thought to the design of a plant whose coal supply may have to be received by rail instead of by water.

Very recently the steam turbine, which is now to be found in several plants, has, also, claimed consideration. Where companies introduce a steam turbine, radical changes from the usual design are necessary, as the boiler room must be larger, in proportion to the generator room, than in an engine driven plant. The general plan of the few large steam turbine street railway power houses that have been designed is to place boilers on both sides of the generator room. One notable exception to the rule is the plant of the Commonwealth Electric Company, in Chicago, where the boilers are placed only on one side of the generator room, and are all on the ground floor. Although the plant is operated for lighting and for stationary motors, and not for street railways, the principle here followed is approved for both fields of work.

Kingsbridge power plant.—The latest and one of the best illustrations of street railway power house construction and equipment is the Kingsbridge power plant, built for the Third avenue division of the Metropolitan Street Railway (Interurban) Company of New York. This plant was built before the statistics in this volume were compiled, but it was not equipped and operated until somewhat later. The interior of the plant is shown in the accompanying illustration.

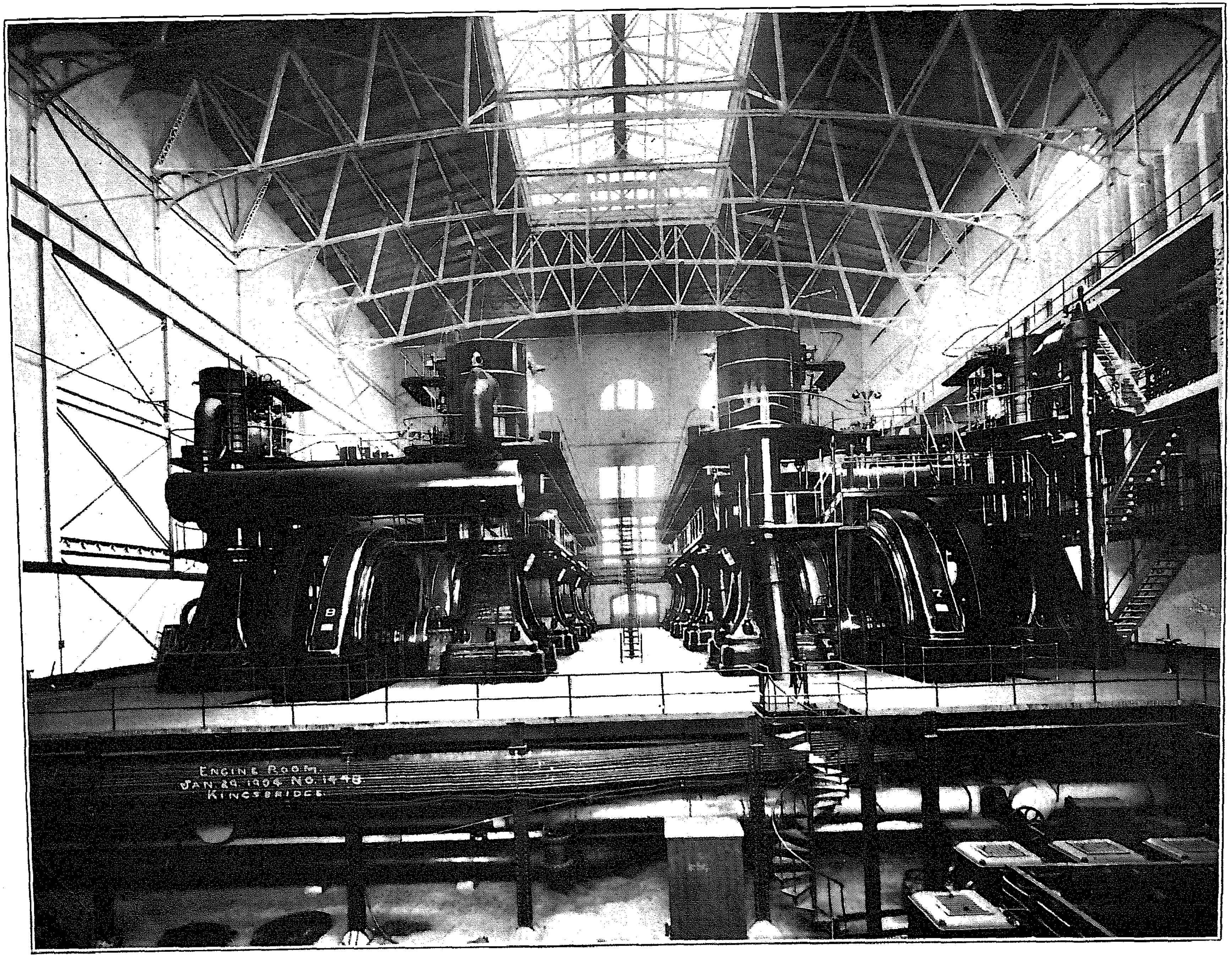
The plant has sixteen 3,000-kilowatt units located in two rows of eight each, in an engine room parallel to the boiler house, which contains two tiers of boilers. The entire structure is 320 feet long and 244 feet wide. The engines are arranged in the usual way on each side of a center aisle, and the boilers are in batteries facing each other on each side of the fire room. This plant has also a wide transverse aisle running crosswise of the house, which, with the longitudinal passageways, virtually separates the plant into four sections. Just inside of the boiler wall in this transverse passage are placed four large barometric condensers, each serving one-quarter of the plant, and any three of them capable of serving the whole plant.

Each quarter of the boiler house has an independent smokestack; but the flues leading to the four stacks are so connected that the gases from one-quarter may be forced to any other, enabling one stack to relay another if, for any purpose, this should be necessary. Economizers are placed in the flues, and the 200-foot stacks, yielding sufficient natural draft for ordinary service, are reinforced by supplementary mechanical draft, by which the effective height of the stacks may be increased to about 400 feet when desired. It will be seen, therefore, that each quarter of the boiler plant is provided with its own stack, economizers, and mechanical draft. Moreover, each quarter is so connected to four of the engines driving 3-phase alternators as to serve primarily one-quarter of the engine room, which, in turn, is connected by suitable exhaust to a condenser large enough for four units. The station may, therefore, be considered as consisting of four independent plants, so connected that they may operate as one entire system, or may be sundered into divisions of two or four as operating conditions may require.

In general design, spacing, and operating characteristics, this station is so laid out that while there is ample room for all required purposes there is no space wasted, the result being that the station covers just 1.11 square feet per horsepower of generating apparatus.

The auxiliaries of the station are, in the main, steam driven, the auxiliary exhaust being utilized to heat the feed water prior to its discharge to the economizers. Ample oil circulating systems are provided, with filtration; and the usual complements of service for coal handling, cold storage, ash handling, etc., are amply provided.

The building is of a very substantial character, and rests upon a substructure of some 18,000 piles, capped with 6-foot monolithic slabs of concrete. The steel framing is somewhat more substantial than is usual in structures of this class, and the building throughout is of a high character. Architecturally, it is of pleasing appearance, plainly, but very substantially finished. The plant as a whole probably represents the highest type of design and construction within the class to which it belongs, particularly in respect to the proportions introduced into the general design, the sufficiency covered in the details, and the care and fidelity with which the construction has been uniformly sustained in keeping with the intent of the design. Among its interesting features, not usually found in power plants,



TYPICAL INTERIOR, MODERN TROLLEY POWER HOUSE, KINGSBRIDGE, NEW YORK CITY.

are the methods provided for handling the engines from a single point on the upper platform, the large central condensing plant, and the relation of the condensing plant to the grouped main units.

Another accompanying illustration is an exterior view of the Pratt street power plant, which supplies current to the Baltimore trolley system. The notable feature in connection with this building is its location at the water's edge, permitting the receipt of fuel direct from ship or barge by a most elaborate and effective system of conveyance.

II.

SUBSTATIONS.

The function of the substation is to distribute the current which the main power plant generates. The growth of the system of generating polyphase, alternating current at one central point, has made substations necessary in different parts of the territory, which receive on "step-down" or receiving transformers this current transmitted over single wires or cables at high pressure. The current passes from these transformers as alternating current of low pressure and is received by rotary converters, a species of the composite double-wound dynamo, at the collector rings, and delivered at the commutator on the other side as direct or continuous current at the normal pressure or voltage used on street railway motors, namely, 500 to 550 volts. This direct current either goes out to the section of the line fed by the substation or is stored up in storage batteries located at the substation.

According to the data given in Supplementary Table 6, the substation equipment of the 105 companies included in the report embraced 926 transformers of 221,459 horsepower, exclusive of 14 for which the horsepower was not reported; 358 rotary converters of an aggregate capacity of 186,688 horsepower, exclusive of 8 for which horsepower was not reported; 20,960 storage battery cells of a reported horsepower of 39,249, the capacity of 1,080 cells not being reported; and 40 miscellaneous machines of 6,235 horsepower, exclusive of 3 for which the horsepower was not reported.

A very large proportion of this equipment is to be found in New York city, where the largest substations are those in connection with the plants of the Interurban or Metropolitan Street Railway system and the Manhattan Elevated Railway.

Manhattan (elevated) system.—The main power station of the Manhattan system is located on the East river between Seventy-fourth and Seventy-fifth streets, while the seven substations for delivering the current received from it are located in different parts of the city. Illustrations of some of the substations on this system are here presented.

The Manhattan elevated substations are generally 50 feet wide by 100 feet long, and have four floors above the basement, the two upper being reserved for storage batteries. The lower floor contains the rotary converters set on concrete foundations. The second floor, in the form of a gallery, contains the substation switchboard and the alternating current transformers, familiarly known as the "statics." Between the galleries a 25-ton crane traverses the space over the converters, the gallery being served by 5-ton cranes. The buildings are of steel construction so designed that the inner columns will carry the heavy loads, thus permitting a symmetrical spread of the large foundations required. The floors are of concrete construction. The battery rooms are paved with vitrified brick laid in asphaltum. All the buildings are provided with electric elevators.

The Manhattan Elevated, while possessing its due proportion of transformers and rotary converters in substations, reported only a small number of storage batteries. The system depends almost entirely upon live current as distinguished from that which is stored up. In this particular there is opportunity for difference of practice between electric railway operations and electric lighting. It would be impossible for a company doing a commercial lighting and stationary motor business to depend upon live current, the supply of which must be renewed incessantly by the generators without any reserve or precautionary measures against breakdown or sudden stoppage. Hence, the storage battery is a vital and essential part of the electric lighting system. In transportation, however, the storage battery is not indispensable and the Manhattan Elevated Company has preferred to rely entirely upon live current.

III.

POWER—CONSUMPTION OF, AND COST.

In a preceding section of this chapter attention has been given to the general statistics of power plant equipment. It is only with regard to electric railways that information as to power production and consumption in the operation of street car lines has been broadly available, or is of value in a technical sense. There are, however, many aspects under which the question of power is of interest to the public, aside from the modus operandi, or the manner in which transportation is facilitated, or the degree to which the form of traction affects the relative congestion of thoroughfares by cars.

For example, according to the statistics which were carefully compiled for several years by the Metropolitan Street Railway Company, of New York, at a time when it had the three systems of animal power, cable, and electric railway, in full parallel operation, it was shown that the benefits to the company were at least equal to those derived by the community at large. During the year 1900 these motive powers were all in use on the best streets for the same kind of traffic, and with a traffic density on the cable and electric lines not greatly differing. Reasons were thus furnished in a practically conclusive manner for the abolition of the cable service, and its entire supersession by electricity. It was also shown that animal power traction is almost universally found uneconomical. It appears from the figures, which were compiled by the Metropolitan Street Railway for its own information, that the percentage of operating expenses to gross earnings in 1900 were 40.5 per cent for electric, 51 per cent for cable, and 73.6 per cent for animal power lines. The profit per car mile was 19.38 cents for electric, 17.10 cents for cable, and 6.82 cents for animal power lines. The superior economy of the electric systems, however, is not fully expressed by these figures. The car-mile unit is different in each case. The old horse car would seat only 16 to 20 passengers, and the cable car about 28; while nearly all the electric cars, at the time of the analysis, would seat from 30 to 50. The cost per passenger carried was 2.02 cents for the electric cars, 2.55 cents for the cable cars, and 3.67 cents for the horse cars. A slight modification of the natural conclusion from these figures must be made, owing to the fact that the cable cars had the advantage of a somewhat denser traffic, while the horse cars were under a disadvantage in having a less average density of travel to deal with than either the cable or electric.

These figures were last published in 1901, by which year the system of the Metropolitan company had been so generally electrified that there was no longer any particular object in going to the expense of making an elaborate study of the comparative results. The advantages of electricity, as well as the greater flexibility of the system, had by that time been demonstrated beyond all doubt. The great main artery of travel—Broadway—had been converted from cable to electricity, so that its figures during the year reported were wholly in the electrical class. It was shown during 1901 that mechanically, the Metropolitan electrical system was operated .09 of a cent per car mile cheaper than in the previous year. This reduction appeared entirely in the cost of fuel and labor, both being due to the employment of larger generating units in the new power house which the company has put into operation.

Power plant capacity.—Before taking up the question of the consumption of current per car mile, etc., it is interesting to study the statistics for power plant capacity which are given in Tables 87 and 88 for companies without and with commercial lighting, respectively, that use steam exclusively to drive their generating dynamos.

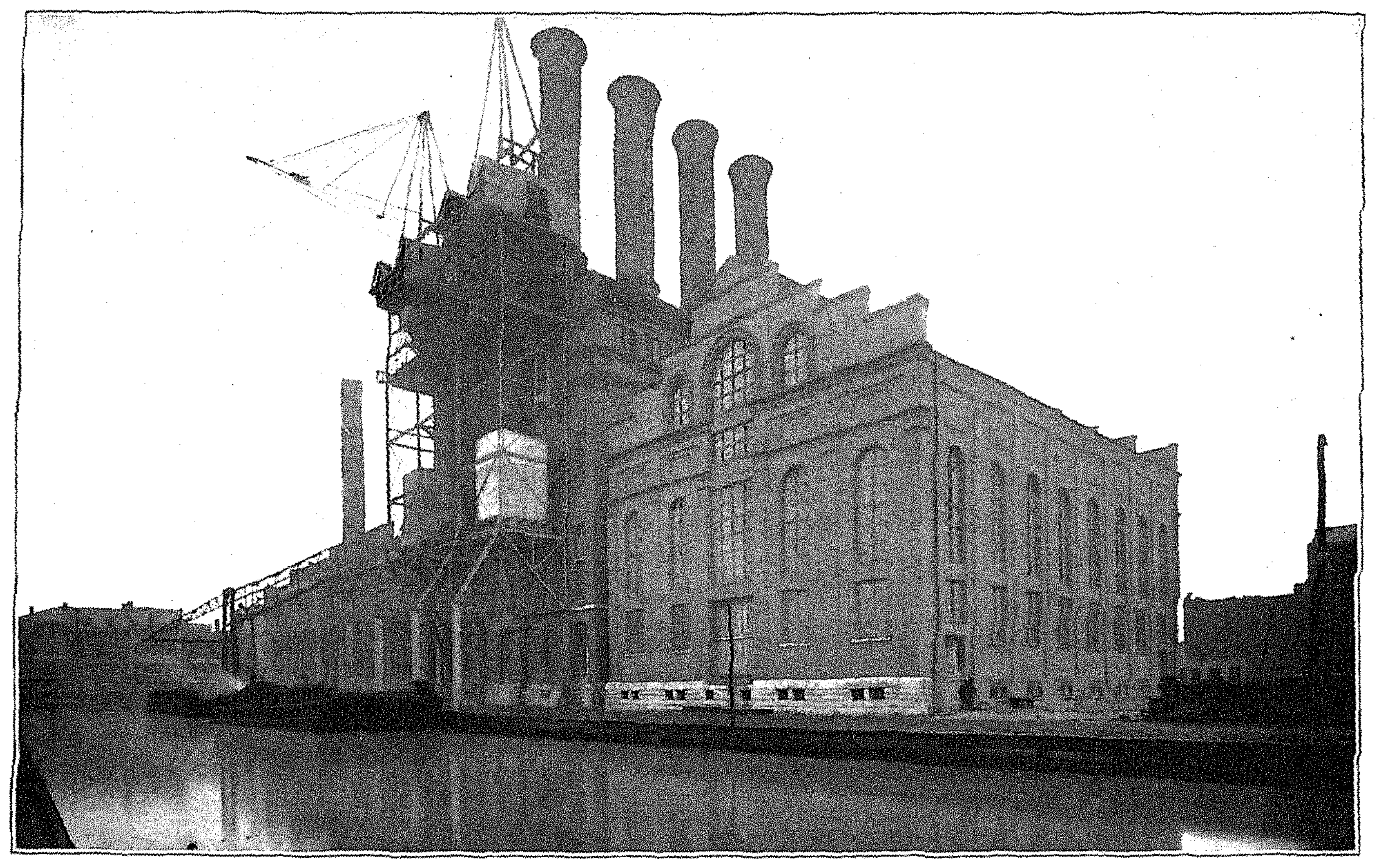
TABLE 87.—POWER PLANT CAPACITY, RAILWAY COMPANIES WHICH DO NOT SELL CURRENT, CLASSIFIED ACCORDING TO POPULATION: 1902.

	Total.	URBAN CENTERS, POPULATION.				INTERURBAN RAILWAYS.	
		500,000 and over.	100,000 but under 500,000.	25,000 but under 100,000.	Under 25,000.	Fast, long.	Other.
Number of street railways using steam exclusively	221	15	12	25	50	31	88
Number of cars	16,771	5,989	3,778	2,256	836	1,167	2,745
Generator capacity in horsepower	366,301	112,832	64,048	42,075	19,133	56,030	72,183
Engine capacity in horsepower	394,967	122,630	66,283	47,765	20,048	62,630	75,611
Boiler capacity in horsepower	298,394	84,975	49,707	34,275	17,597	47,418	64,427
Generator capacity per car, in horsepower	21.8	18.8	17.0	18.7	22.9	48.0	26.3

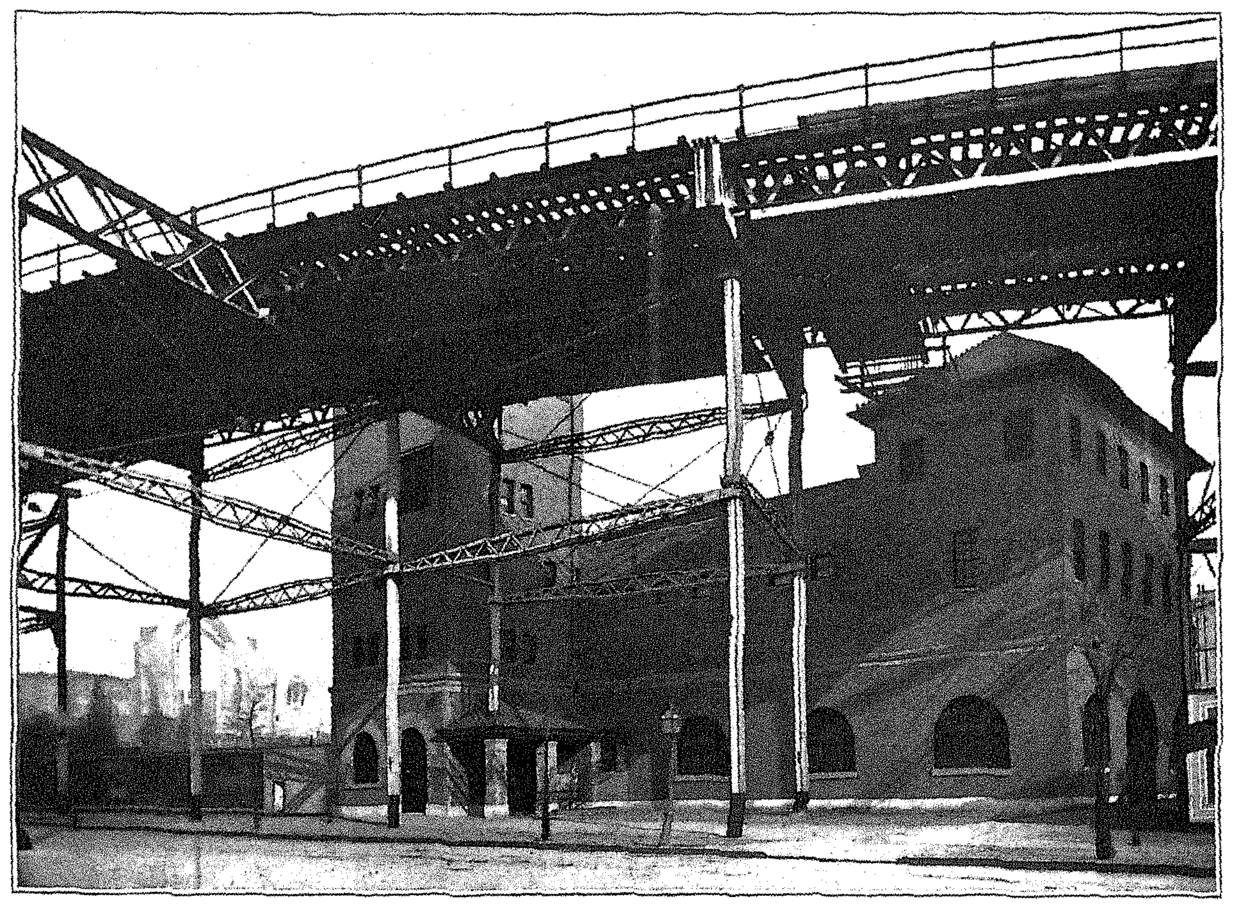
TABLE 88.—POWER PLANT CAPACITY, RAILWAY COMPANIES WHICH SELL CURRENT, CLASSIFIED ACCORDING TO POPULATION: 1902.

	Total.	URBAN CENTERS, POPULATION.				INTERURBAN RAILWAYS.	
		500,000 and over.	100,000 but under 500,000.	25,000 but under 100,000.	Under 25,000.	Fast, long.	Other.
Number of street railways using steam exclusively	185	3	13	23	84	13	49
Number of cars	15,522	3,714	3,578	1,896	1,622	566	4,151
Generator capacity in horsepower	378,046	51,031	82,233	49,610	62,857	23,152	109,163
Engine capacity in horsepower	402,270	57,800	86,165	57,805	60,880	24,555	116,115
Boiler capacity in horsepower	279,660	31,020	57,465	38,385	55,071	17,340	80,379
Generator capacity per car, in horsepower	24.4	13.7	23.0	26.2	38.8	40.9	26.3

It will be seen from Table 87 that 221 street railway systems whose current was employed exclusively in street car operation, with 16,771 cars in operation, had a generating dynamo capacity of 366,301 horsepower, an average per car of 21.8 horsepower. In cities above 25,000 population the generating capacity per car varied very little, being 18.8 horsepower per car for the larger cities over 500,000 population; 17 horsepower per car in cities between 100,000 and 500,000; and 18.7 in cities of between 25,000 and 100,000. In a group of 50 systems in communities with a population under 25,000, and with only 836 cars, the generating capacity rose to 22.9 horsepower, indicating the relatively greater inefficiency which necessarily attends the operation of a very small system, as compared with a larger one. It is not to be understood, however, that all this provision



TYPICAL WATER SIDE STREET RAILWAY POWER HOUSE, BALTIMORE, MARYLAND.



MANHATTAN ELEVATED RAILWAY STATION AND POWER SUBSTATION, NEW YORK CITY.

per car was necessarily called upon at one and the same time, or was required all of the time, although there may be busy hours of heavy load when all the machinery is called upon to take its share of duty. It is important to point out in this connection that the interurban lines, of which 31 are specifically considered, have provision per car much greater than in the cities.

The fast, long interurban lines, with 1,167 cars, had a total generating capacity of 56,030 horsepower, an average per car of 48 horsepower. This is very nearly three times as much as the provision made in urban centers of between 100,000 and 500,000 population. There are two chief reasons for the great difference. One is the heavier weight of the modern interurban car, as well as the large amount of bulky freight and express business now carried by them; and the second is the fact that, as a large proportion of the interurban plants are of recent construction, the power stations would almost invariably be equipped with a generating capacity considerably beyond the immediate requirements of the road. While it is comparatively easy to add to the rolling stock at need, it is a much more difficult and costly performance to enlarge a power plant, and add new engines, boilers, and dynamos.

No attempt has been made in preparing Table 88 to distinguish the proportions of current going to the various services. The 185 electric railways included in the table reported 15,522 cars and a total generating capacity of 378,046 horsepower—an average of 24.4 horsepower per car. This average is only 2.6 horsepower greater than the average shown in Table 87 for the companies that do not sell current. It might, on a priori grounds, be suggested that companies selling current could operate more regularly and more nearly at the point of maximum efficiency, and that therefore the generating capacity per car required from their plants would not be increased by an amount proportionate to the increase of business done. Thus, it might be possible for some companies to sell current from a plant having no greater capacity than would be necessary for the operation of its cars during rush hours. But it can hardly be said that the statistics in Tables 87 and 88 either confirm or weaken such an inference. The slight difference shown for the two classes of companies in the country as a whole would seem to be confirmatory; and the fact that an actually lower average is shown for the three companies with lighting plants in cities of 500,000 and over would seem to add even greater plausibility to the inference. But against this has to be set the fact that in cities of fewer than 25,000 inhabitants, where a large majority of the companies with lighting plants operate, these companies show an average generating capacity nearly 70 per cent greater than is shown for the other class of companies. So many other forces are operative in determining the figures in the two tables that it would probably be unwise to attempt any generalized conclusion from them as to the relative efficiency of the two classes of street railway electric plants.

In the case of interurban railways, again, the companies selling current report a lower generating capacity per car than do the companies that sell no current. It would probably be an utterly unsafe inference to conclude that the difference in favor of the companies that sell current is due to the possibility of working under conditions of superior efficiency. Date of construction and conditions of operation have evidently exerted a preponderating influence. Table 89 deals with the current consumption of a group of 307 selected electric railways, and does not include any roads that buy or sell power, so that the figures are as free as possible from complications of that character, although, incidentally, they include a certain but small amount of car mileage due to freight, mail, express, and other services.

These roads reported a power consumption of 1,048,799,599 kilowatt hours; operated a total of 491,023,555 car miles, and carried 1,936,860,800 passengers. This gives a power consumption per car mile of 2.14 kilowatt hours, and a traffic of 4 passengers to the car mile run. This is a very fair average of traffic on such power consumption, although, as will be seen, the table shows some very wide variations, not altogether explicable on the surface. Thus, for instance, Maryland reported one of the largest consumptions of power per car mile, 7.68 kilowatt hours. This is not due probably to the density of the traffic, 7.3 passengers per car mile, for power consumption does not increase proportionately with increase of traffic, but is due rather, as is the high traffic figure itself, to the very small car mileage. Vermont, whose figures for power consumption per car mile are the highest in the table, 8.67 kilowatt hours, has a mileage of only 145,591 car miles and difficult operating conditions, because of the hilly nature of the country and the long and severe winters. The state of Alabama, with only 0.68 kilowatt hours per car mile, has the smallest power consumption of all the states, but West Virginia shows better operating results with a power consumption of 0.72 kilowatt hours per car mile, 3,167,015 car miles run, and a traffic of 3.9 passengers to the mile. To take a single large system for illustration, the Union Traction Company, of Philadelphia, whose system is entirely electric, reported a total of 325,801,963 passengers carried, a car mileage of 59,721,423 miles, and a power consumption of 104,222,363 kilowatt hours. These figures give 5.5 passengers per car mile, and a power consumption of about 1.75 kilowatt hours per car mile. This is a fairly typical figure for a road with heavy and dense traffic and with cars of good size operated over tracks in normal condition.

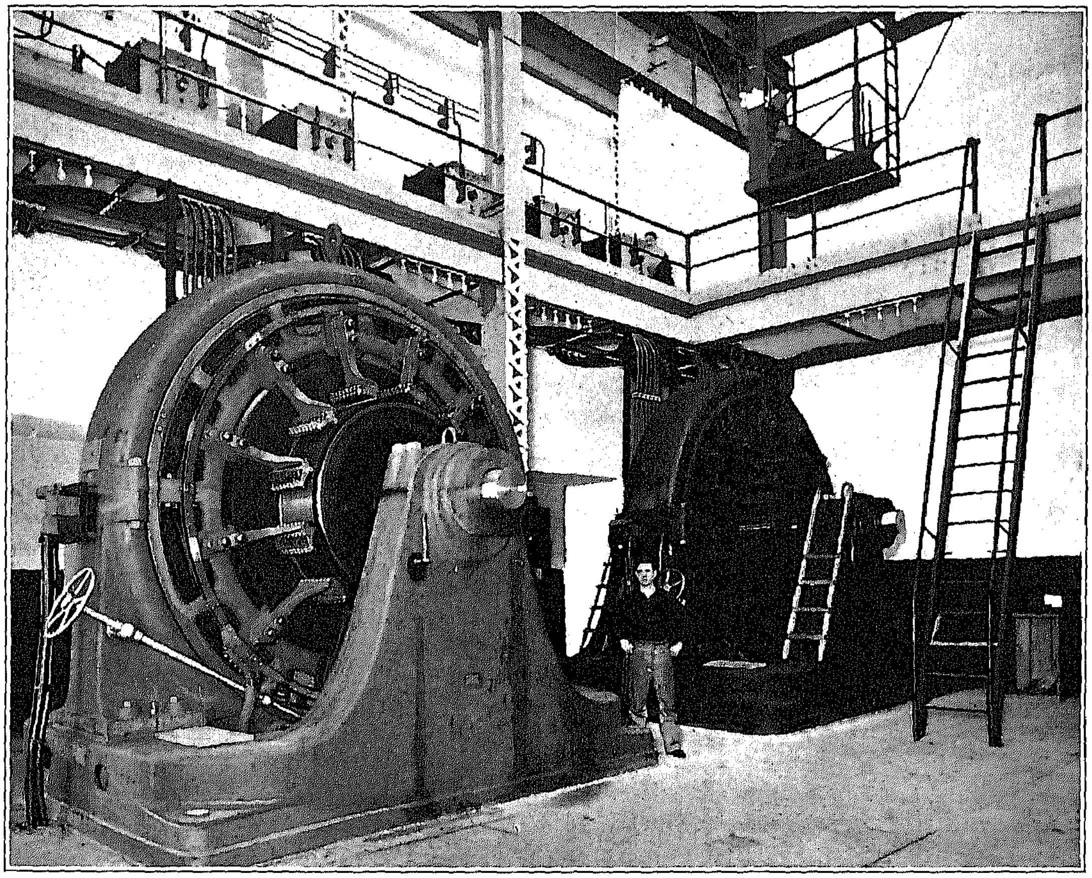
TABLE 89.—POWER CONSUMPTION, SELECTED ELECTRIC RAILWAYS, BY STATES: 1902.

STATE OR TERRITORY.	Number of railways.	Kilowatt hours.	CAR MILEAGE.			Passengers carried.	Power per car mile in kilowatt hours.	Passengers per passenger car mile.
			Total.	Passenger.	Freight, mail, express, and other.			
United States	307	1,048,799,599	491,023,555	487,217,352	3,806,203	1,936,860,800	2.14	4.0
Alabama	1	216,445	316,095	313,380	2,715	780,200	0.68	2.5
Arizona	1	459,900	255,500	255,500	....	750,000	1.80	2.9
Arkansas	2	630,810	225,437	224,857	580	332,367	2.80	1.5
California	8	25,242,199	16,384,206	16,295,572	88,634	52,654,040	1.54	3.2
Colorado	1	11,600,000	6,393,755	6,393,755	....	30,910,210	1.81	4.8
Connecticut	10	37,334,257	12,216,040	11,851,028	365,012	44,228,633	3.06	3.7
Delaware	3	7,730,899	3,006,798	2,969,238	37,560	9,956,559	2.57	3.4
District of Columbia	2	21,333,645	11,920,796	11,870,385	50,411	46,085,925	1.79	3.9
Florida	1	492,750	385,988	385,988	....	998,290	1.28	2.6
Idaho	1	219,500	164,250	164,250	....	314,840	1.34	1.9
Illinois	20	76,309,232	34,383,702	34,310,602	73,100	107,962,880	2.22	3.1
Indiana	16	44,774,563	17,826,239	17,686,739	139,500	57,056,001	2.51	3.2
Iowa	8	12,157,823	6,529,398	6,409,032	120,366	21,366,872	1.86	3.3
Kansas	5	1,872,048	1,362,307	1,362,307	....	4,335,697	1.37	3.2
Kentucky	7	18,414,198	13,434,959	13,409,024	25,935	50,826,055	1.37	3.8
Louisiana	3	24,737,875	17,024,959	17,024,959	....	50,678,573	1.45	3.0
Maine	7	13,051,470	4,862,065	4,782,977	79,088	19,346,697	2.68	4.0
Maryland	2	864,783	112,648	66,740	45,908	487,756	7.68	7.3
Massachusetts	31	126,316,167	67,867,134	67,597,249	269,885	311,918,174	1.86	4.6
Michigan	12	70,473,835	26,554,412	26,010,537	543,875	95,717,676	2.65	3.7
Minnesota	1	3,374,391	2,258,884	2,258,884	....	9,178,517	1.49	4.1
Missouri	4	99,918,577	33,867,907	33,553,346	314,561	135,704,075	2.95	4.0
Montana	1	1,669,510	807,380	766,500	40,880	4,731,000	2.07	6.2
Nebraska	1	10,333,150	5,007,074	5,007,074	....	18,540,000	2.06	3.7
New Hampshire	4	1,868,373	1,120,067	1,119,799	268	3,272,735	1.67	2.9
New Jersey	10	11,253,793	6,242,055	6,226,031	16,024	23,036,234	1.80	3.7
New York	39	54,518,421	21,371,491	21,056,843	314,648	72,467,958	2.55	3.4
Ohio	36	141,903,196	68,057,788	67,360,472	697,316	232,958,540	2.09	3.5
Oregon	1	438,000	140,416	140,416	....	300,000	3.12	2.1
Pennsylvania	42	173,727,592	85,103,240	84,720,559	382,681	422,890,265	2.04	5.0
Rhode Island	5	32,165,675	9,955,144	9,832,162	122,982	52,004,623	3.23	5.3
Tennessee	2	4,012,810	3,765,321	3,765,321	....	16,898,823	1.07	4.5
Texas	4	7,744,794	4,257,582	4,204,344	53,238	13,856,859	1.82	3.3
Utah	1	556,625	292,100	292,000	100	861,910	1.91	3.0
Vermont	2	1,262,170	145,591	132,393	13,198	472,667	8.67	3.6
Virginia	5	4,351,318	1,830,490	1,822,752	7,738	5,000,368	2.38	2.7
West Virginia	3	2,287,015	3,167,015	3,167,015	....	12,501,879	0.72	3.9
Wisconsin	5	3,181,790	2,407,322	2,407,322	....	5,477,402	1.32	2.3

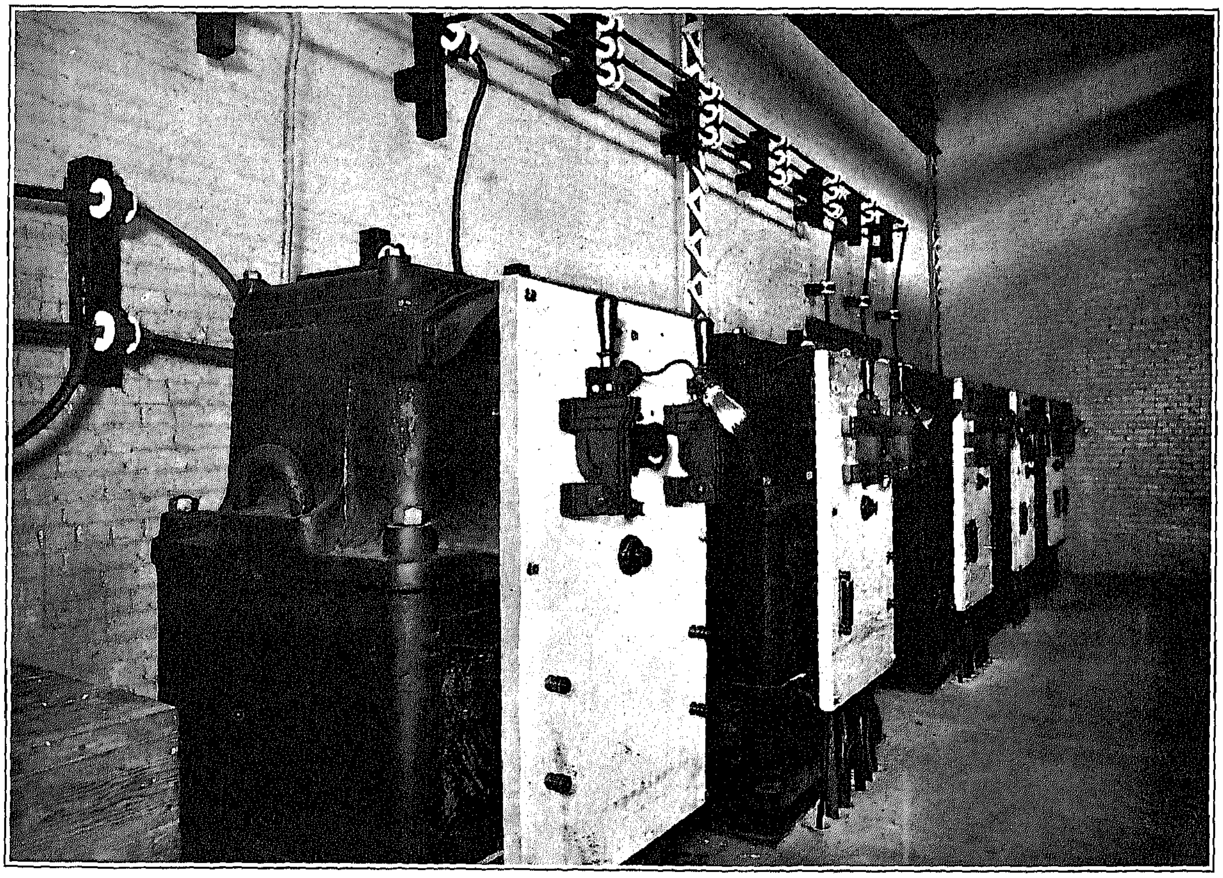
In the computations as to the consumption per car mile no allowance has been made for car lighting and car heating. Of 62,369 lighted cars, 55,703 were lighted by electricity. In the aggregate the consumption of power for this purpose would be very considerable; but it is obvious that no exact figures can be obtained, as the lighting varies materially with the season of the year, the state of the weather, the number of cars on the road, etc. This is also true of electric heating. Out of 30,159 cars heated, 19,021 had electric heaters. It was pointed out in the discussion of car heating that in winter weather to maintain a temperature of 54° in an ordinary car 3,160 watts would be required, and that this might be kept up for several hours. The power consumption for car heating undoubtedly is large. To the extent, therefore, that current is employed in car heating and car lighting, the current charged against car propulsion would be lessened. As a matter of fact, car lighting and car heating are as much a part of car operation as the act of propelling it along the track. But it would be obviously unfair to take the power consumption per car mile or per car hour in a city where little lighting and heating of cars was necessary and compare it with the consumption required in a city with long winters and short days.

Car hours.—In Table 97 statistics of car mileage are given for all roads. In addition, 390 companies report the number of car hours of operation. The car hour is a relatively new unit, having been adopted as a standard unit of comparison in 1901, after being under discussion for some time by the American Street Railway Accountants' Association. It makes but little difference what unit is used as a basis of comparison so long as the purpose is simply to show whether the earnings or the expenses are proportionately above or below those of a similar period on the same system; but to make a comparison with another system which has a different speed schedule, length of day operation, size of cars, and different physical conditions of operation, it is essential that the unit should be a comparable one, and the principal fact which companies wish to compare is cost of operation. The car-mile unit is to a certain extent a measure of speed, but increase of speed would not materially affect the cost of operation.

Another disturbing element in the use of the car mile as the unit is the trailer. When trailer cars are used regularly and to any considerable extent their car mileage is estimated separately. But, as has been pointed out, it is cheaper to operate one 40-foot motor car than a 20-foot motor car and a 20-foot trailer



THE ROTARY CONVERTERS IN A MANHATTAN ELEVATED RAILWAY SUBSTATION.



THE STEP-DOWN TRANSFORMERS IN A MANHATTAN ELEVATED RAILWAY SUBSTATION.

hitched together. If two roads are compared, the one using 40-foot motor cars and the other a motor and a trailer of the same combined length, and if they be operated at the same speed, headway, etc., the first would show a cost, say, of 12 cents per car mile. The other one, on account of the double mileage indicated, would show, allowing for the fact that but one conductor would be needed, a little more than one-half of 12 cents per car mile for the two cars. Again the car mile does not take into account questions of grades. A car going uphill takes a great deal of power, while a car going downhill should take none, and might even become a source of current return to the line. As all grades and loads affect speed, mileage could not be a fixed standard without some sort of adjustment.

In the earlier stages of the introduction of the car-hour unit it was contended that the cost of ascertaining the number of motor car hours would be such as to hinder its adoption or use on a large system. According to street railway accountants, car hours are more easily determined than car mileage, and that the cost of ascertaining the facts is less, especially in cities where a large number of cars are run without reference to schedule time, but are operated wherever and whenever deemed necessary. Experience has shown that the reports of mileage made by trainmen are only approximately correct, but it is evident that the record of the time of starting a car and returning it to the barn can be accurately kept and verified. This seems to be the best and most accurate unit yet suggested. The arguments in favor of the car hour, as compared with the car mile, summed up briefly are as follows:

(1) The absence of the element of speed, which from the standpoint of cost is destructive of correct comparison on the car-mile basis.

(2) Conductors' and motormen's wages, the principal item of expense, are paid by the car hour and not by the car mile.

(3) Operating expenses are more directly affected by the length of time of operation than by the mileage made.

Perhaps the value of the car-mile and car-hour records can best be illustrated from a concrete example, such as that afforded by the Camden and Suburban Railway Company, of Camden, N. J. For the past four or five years that company has used the car-hour unit in connection with the car mile, and all its statistics are worked out on both bases. It will be noted, for example, that in Table 97 the company reported 319,066 car hours, a total of 2,501,430 car miles, carrying a total of 8,217,072 passengers. The output of power reported by the system was 3,734,315 kilowatt hours. The company has found the car-hour unit of value because it is the only basis upon which the labor factor can be calculated. On the other hand, the car-mile unit is after all the only practicable one for closely figuring out wear of parts and depreciation of rolling stock. An illustration of the value of using both units is furnished by the company in a comparison between one of the city lines and one of the suburban lines. The city line had receipts for the year 1902–3 of 21.46 cents per car mile, and $1.24 per car hour. The suburban line had receipts of 14.69 cents per car mile and $1.90 per car hour. In other words, the suburban line had receipts which were 32 per cent less per car mile, and 53 per cent more per car hour than the city line. If, therefore, the car-mile basis alone had been taken, the suburban line would probably be viewed as unprofitable compared with the usual standard of receipts per car mile, whereas the car-hour basis was sufficient to show that the line was operated at a good margin of profit.

The value of the car-hour unit may be again illustrated from the Camden and Suburban system, whose Moorestown line formerly terminated at Merchantville. When the line was extended 5 miles farther, to Moorestown, the question arose as to whether this extension would pay. An additional fare of 5 cents was charged over the extension. The added service required an addition of 1,360 car hours a month. An investigation showed that 80 per cent of the traffic to and from Moorestown was through traffic, and that the 5,000 population was carried on an average 120 times per capita per year. This made the additional receipts per month about $5,000. Taking this sum and dividing it by the 1,360 extra car hours per month, the receipts for the extension were shown to be $3.60 per car hour, a proof to the company and to the community of the value of the extension.

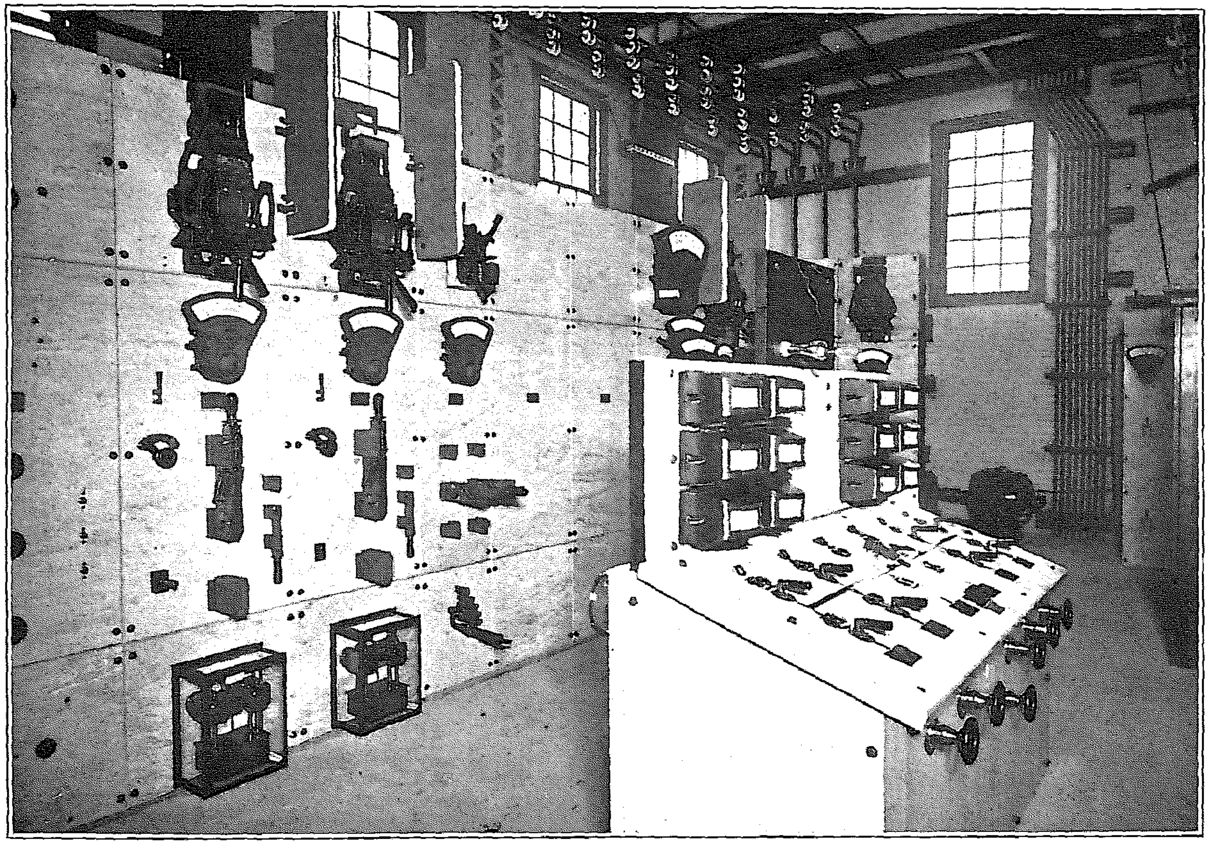
The unit has proven of further value in analyzing expenses, for example, in the separation of labor cost and the isolation of what may be called the "lay-over" expenses. For example, a short or a long lay-over would not affect the wear and tear of a car, or the power cost or consumption of kilowatt hours, but it would enter into the labor cost indirectly, which, upon lines operating at different speeds, can best be figured on the car-hour basis.

Tables 53 and 54, which present analyses of operating expenses of railways classified according to population of urban centers served, give statistics that must be considered in connection with the subject of power. The cost of operation of power plants in cities of over 500,000 population amounted to $9,641,891, or 14.3 per cent of the total operating expenses. In cities between 100,000 and 500,000 population the ratio was almost exactly the same, or 14.2 per cent; in cities from 100,000 down to 25,000 population, it was 16.2 per cent; in cities under 25,000 population, 24.5 per cent. In the separate groups of interurban lines, the ratio of power plant cost to total operating expenses was 22 per cent on the fast long lines, and 20.2 on the other.

Thermal efficiency.—Upon the general subject of power station economies in the matter of output and cost per kilowatt hour unit, many facts and opinions might be offered which would aid in interpreting the statistics of the subject as given in this volume. It will perhaps be sufficient to give here the substance of a paper on power station economy presented before the American Institute of Electrical Engineers, by Prof. W. E. Goldsborough and Mr. P. E. Fansler, which embodied the results of careful tests made during the year 1902 in regard to the expense incurred in maintaining the power stations of the Union Traction Company of Indiana. The plant then comprised eight 400-horsepower water tube boilers; three engines, each with a maximum capacity of 2,000 horsepower; and three 1,000-kilowatt 3-phase generators directly connected with each engine. The results of the tests of the thermal efficiency of the plant are as follows: The efficiency of the furnace and boiler was 79.6 per cent—i. e., 79.6 per cent of the whole heat in the coal was delivered in the steam by the boilers to the engines. The average thermal efficiency of conversion between the boilers and engine cylinders is 9.11 per cent; i. e., 9.11 per cent of all the heat delivered in the form of steam by the boilers was converted into work in the cylinders of the main engines. This value of 9.11 per cent credited against the engines includes the steam used in the auxiliaries. If the assumption is followed out that 15 per cent of the steam delivered by the boilers was consumed by the auxiliaries, the thermal efficiency of the engines would be 10.7 per cent. The average total thermal efficiency of the plant was 7.25 per cent from the coal pile to the engine cylinders, and the total average thermal efficiency of the plant from the coal pile to the switchboard; i. e., the ratio per cent of the energy delivered by the generators to the total heat in the coal was 6.39 per cent.

Although it is frequently stated that the thermal efficiency of the steam engine at a maximum is about 25 per cent, it is impossible that any engine of this class working under these conditions should convert more than 12 per cent of the heat of the coal into work. This record of a thermal efficiency of 6.39 per cent up to and including the switchboard showed high economy as compared with those shown by some other stations of a similar character. Thus the total thermal efficiency of the Harrison Street station of the Chicago Edison Company, with large direct connected reciprocating engines has been estimated to be 4.5 per cent, while that of the generating station of the former Blue Island (Chicago) Storage Battery Road was found to be 5.5 per cent. Indiana block coal was used, delivered at a cost of $1.35 per ton. On this basis the cost of developing one kilowatt hour was .28 of a cent. This kilowatt-hour unit of cost may be taken as the fundamental basis for estimating the efficiency of any station; figures of this cost in various stations vary between 0.246 and 1.016 cents. Professor Goldsborough, in the report to which reference has been made, said that the station tested by him delivered to the line 6.23 per cent of the total energy of the coal, but that only 3.65 per cent of the total energy got to the cars. The efficiency of transmission as between the station and the cars was, therefore, only 50 per cent. In the discussion following the report, Mr. M. H. Gerry said that if every loss between the electrical input at the cars, and the car axle were included, the total efficiency of the plant would certainly be reduced 25 to 30 per cent more—to about 2 per cent. Professor Goldsborough admitted that this was a fair estimate, but he pointed out that power was developed so cheaply that this final waste became a small factor, one passenger per car nearly paying the whole cost of power used by a car from Indianapolis to Muncie, although the fare was only 1 cent a mile. Mr. Gerry contended that the plant was not an example of high efficiency or even of average efficiency. Professor Goldsborough replied that the plant had a very high financial efficiency, which he considered to be better than a high power efficiency. To reduce the transmission losses would be to increase the capital charge, and such an increase might more than balance the present high cost for coal. If a low-class generating station, low-class transformers, low-class rotaries, and cheap batteries were put in, the cars would not get the required per cent of power of the total energy generated. The station had the highest class of generating machinery, and should it become necessary to increase its earning capacity all that would have to be done would be to increase the copper in the lines. The regular voltage was 18,000, but in extending its system to Logansport the company had used 32,000 volts. Mr. H. G. Stott, of the Manhattan Elevated system, said that the ultimate object in any power plant was to deliver a kilowatt hour to the receiving apparatus at a minimum cost, and that there is no other object in a power plant. If the coal is expensive, an extremely efficient and expensive plant must be put in; but if coal is very cheap, one can afford to sacrifice a good deal of thermal efficiency in order to reduce the cost charges of the plant. In the end, however, one must consider the problem as a whole; that is, the cost of the kilowatt hour delivered at the receiving apparatus. The total cost of the delivery of power is the real test. In the New York Manhattan plant he said the cost of coal was 70 per cent of the total operating expenses up to the track of the elevated road, and consequently an extremely efficient distributing system and power plant were required. He thought that any comparison of efficiencies was unfair when calculated merely on the ratio of indicated horsepower to kilowatt-hour output.

With regard to the efficiency of transmission and its relation to the consumption of current, it may be repeated that this varies greatly and depends upon a number of factors, especially those connected with the length and condition of the line, the pressure employed, the number of substations, the amount of transformation,



SWITCHBOARD IN A MANHATTAN ELEVATED RAILWAY SUBSTATION.

etc. These questions are more complicated, and perhaps more interesting in the case of the longer interurban roads, and the results of some recent tests on the efficiency of transmission on one of the large interurban railway systems in the Middle West are therefore given here pertinently. The system referred to comprised about 100 miles of track built for the most part over private right of way, and was supplied with current from a single power plant at a line pressure of 26,000 volts. As the maximum distance from the station to the farthest point at which current was delivered was 60 miles, it is clear that the station was not exactly midway of the track. Current was generated by 3-phase alternating dynamos. The output measured at the generator terminals at 2,300 volts for the period of six weeks covered by the test was 970,000 kilowatt hours. This current was raised to the pressure of 26,000 volts made by step-up transformers, received by step-down transformers at five substations, and delivered to the line for the motors as direct current at a pressure of 500 to 550 volts. The output of the rotaries to the operation line during this period was 803,000 kilowatt hours, showing a loss in the transmission system of about 17 per cent. This included the loss in the step-up transformers, the transmission circuits, the substations step-down transformers, and the rotary converters. The loss in the apparatus was estimated at about 121,000 kilowatt hours, or 11.9 per cent, and the loss in the transmission line was put down at 46,000 kilowatt hours, or 5.1 per cent. The load on the power plant and the line was steadied by means of a storage battery and a carefully adjusted "booster" at the farthest substation. These figures may be taken to represent a high transmission efficiency.

STREET RAILWAYS OPERATING ELECTRIC LIGHT AND POWER PLANTS.

As already explained, a number of street railway companies generate electricity for sale to other roads or for light, power, or other purposes. If, in such cases, the system of accounts used by the company permitted the preparation of separate and complete reports for the street railway plant and the electric light and power plant, respectively, separate reports were obtained. If the system of accounts did not permit of such separation, one report was secured for the entire plant. Where possible, the companies were required to give separately the amount of revenue derived from the sale of electric current for light or power, and the character of such service.

Tables 90 and 91 present these statistics for the 118 companies reporting.

Table 90.—INCOME—ELECTRIC LIGHT AND POWER PLANTS OPERATED BY STREET RAILWAY COMPANIES, BY STATES: 1902.

STATE.	Number of companies.	Aggregate.	COMMERCIAL OR PRIVATE LIGHTING.			PUBLIC LIGHTING.			MOTOR SERVICE.	Electric railway service.	Electric heating.	Charging automobiles.	All other electric service.	Miscellaneous.
			Total.	Arc. Amount.	Incandescent. Amount.	Total.	Arc. Amount.	Incandescent. Amount.	Amount.					
United States....	118	$6,469,726	$4,074,684	$660,279	$3,414,405	$1,417,985	$1,267,384	$150,601	$768,040	$6,630	$77	$9	$4,390	$197,911
Alabama	4	318,660	257,454	35,055	222,399	32,712	30,106	2,606	26,345	....	....	....	500	1,649
Florida	3	110,209	84,657	9,441	75,216	11,900	9,660	2,240	13,652	....	....	....	....	....
Georgia	7	722,728	421,024	112,940	308,084	173,183	153,503	19,680	119,260	....	....	....	233	9,028
Illinois	4	161,070	118,620	21,929	96,691	6,458	6,458	....	23,038	395	....	....	3,856	9,203
Iowa	8	291,142	154,945	23,586	131,359	75,435	71,515	3,920	40,043	....	....	....	....	20,719
Maine	3	101,892	67,739	7,978	59,761	11,856	10,904	952	15,141	....	....	....	....	7,156
Michigan	6	162,549	106,490	9,595	96,895	42,090	36,987	5,103	9,340	....	....	....	....	4,629
Mississippi	3	98,838	46,232	7,670	38,562	43,547	37,441	6,106	8,982	....	77	....	....	....
Missouri	3	163,406	138,514	3,533	134,981	10,250	9,920	330	2,240	....	....	....	....	12,402
New York	10	413,782	243,233	19,969	223,264	140,998	97,988	43,010	28,172	....	....	....	....	1,379
North Carolina	5	155,770	86,919	6,104	80,815	32,486	30,989	1,497	36,365	....	....	....	....	....
Ohio	11	587,967	374,822	45,229	329,093	147,225	143,725	3,500	53,382	....	....	....	....	13,038
South Carolina	3	171,561	99,128	7,942	91,186	33,993	33,201	792	22,127	....	....	....	....	16,318
Virginia	7	359,158	261,246	75,248	185,998	65,954	62,441	3,513	28,400	....	....	....	....	3,558
Washington	4	618,385	439,358	95,182	344,176	44,544	22,948	21,596	76,635	1,795	....	....	....	56,053
West Virginia	3	105,102	67,181	2,975	64,206	36,253	36,253	....	1,668	....	....	....	....	....
Wisconsin	9	689,572	368,540	90,894	278,146	217,277	215,334	1,943	77,166	....	....	....	....	26,589
All other states[1]	25	1,237,935	739,082	85,509	653,578	291,824	258,011	33,813	186,084	4,440	....	9	301	16,195

[1] Includes states having less than 3 companies in order that the operations of individual companies may not be disclosed. These companies are distributed as follows: Arkansas, 2; California, 2; Colorado, 2; Connecticut, 2; Delaware, 1; Indiana, 2; Kansas, 1; Kentucky, 2; Louisiana, 1; Maryland, 1; Minnesota, 1; Montana, 1; Nebraska, 1; New Hampshire, 1; New Jersey, 2; Oregon, 1; Tennessee, 2.

TABLE 91.—DETAILED DESCRIPTION OF SERVICE—ELECTRIC LIGHT AND POWER PLANTS OPERATED BY STREET RAILWAY COMPANIES, BY STATES: 1902.

STATE.	ARC LIGHTING—NUMBER OF LAMPS IN SERVICE.															
	Aggregate.	Total.				Direct current.				Alternating current.				All other.		
		Commercial or private.		Public.		Commercial or private.		Public.		Commercial or private.		Public.		Commercial or private.		Public.
		Open.	Inclosed.	Open.	Inclosed.	Open.	Inclosed.	Open.	Inclosed.	Open.	Inclosed.	Open.	Inclosed.	Open.	Inclosed.	Open.
United States	33,863	2,582	13,603	10,868	6,810	2,418	6,459	10,495	1,072	1	7,069	8	5,738	168	75	365
Alabama	1,291	449	442	325	75	449	388	325	....	....	54	....	75	....	....	....
Florida	222	103	55	....	64	103	....	....	....	....	55	....	64	....	....	....
Georgia	4,347	238	2,092	761	1,256	238	1,294	761	238	....	798	....	1,018	....	....	....
Illinois	817	235	328	....	254	235	295	....	254	....	33	....	....	....	....	....
Iowa	1,603	133	388	812	270	133	84	812	40	....	304	....	230	....	....	....
Maine	431	25	230	115	61	25	115	115	30	....	115	....	31	....	....	....
Michigan	869	30	286	352	201	30	36	352	....	....	250	....	201	....	....	....
Mississippi	477	....	112	132	233	....	....	132	....	....	112	....	233	....	....	....
Missouri	203	37	5	111	50	37	....	111	....	....	5	....	50	....	....	....
New York	2,594	56	1,070	964	504	55	65	964	....	1	1,005	....	504	....	....	....
North Carolina	613	12	174	325	102	12	....	325	....	....	174	....	102	....	....	....
Ohio	2,933	24	518	1,838	553	24	90	1,838	....	....	353	....	553	....	75	....
South Carolina	693	....	236	....	457	....	37	....	198	....	199	....	259	....	....	....
Virginia	2,983	219	1,710	757	297	219	933	757	100	....	777	....	197	....	....	....
Washington	1,854	116	1,416	19	303	116	1,263	19	121	....	153	....	182	....	....	....
West Virginia	572	....	70	75	427	....	....	75	....	....	70	....	427	....	....	....
Wisconsin	4,715	387	1,778	1,871	679	387	1,277	1,871	91	....	501	....	588	....	....	....
All other states[1]	6,646	518	2,693	2,411	1,024	350	582	2,038	....	....	2,111	8	1,024	168	....	365

STATE.	INCANDESCENT LIGHTING—NUMBER OF LAMPS IN SERVICE.									STATIONARY MOTOR SERVICE.		Number of mechanical meters on consumption circuits.
	Aggregate.	Total.		16-candlepower.		32-candlepower.		All other.		Number of motors of all kinds.	Total capacity in horsepower.	
		Commercial or private.	Public.	Commercial or private.	Public.	Commercial or private.	Public.	Commercial or private.	Public.			
United States	1,442,685	1,423,659	19,026	1,313,303	13,065	31,597	1,119	78,759	4,842	10,049	35,688	[2]56,601
Alabama	50,704	50,045	659	47,705	659	2,203	....	137	....	648	936	2,606
Florida	19,872	19,541	331	19,408	323	127	8	6	....	137	714	880
Georgia	136,978	135,604	1,374	132,630	900	1,470	30	1,504	444	2,066	4,844	5,121
Illinois	42,426	42,426	....	37,883	....	226	....	4,317	....	202	611	1,475
Iowa	62,284	61,924	360	57,610	60	1,830	50	2,484	250	549	1,479	3,338
Maine	39,443	39,379	64	38,079	....	300	39	1,000	25	129	1,011	1,139
Michigan	43,389	41,169	2,220	36,577	2,130	1,134	90	3,458	....	136	700	1,857
Mississippi	12,887	11,890	997	11,290	997	100	....	500	....	295	198	714
Missouri	66,130	66,075	55	45,000	50	75	5	21,000	....	87	119	1,553
New York	100,561	98,812	1,749	86,950	691	2,257	47	9,605	1,011	336	2,662	[2]6,217
North Carolina	31,742	31,498	244	28,132	204	423	40	2,943	....	105	1,544	1,273
Ohio	189,708	188,065	1,643	186,683	1,613	682	20	700	10	513	3,589	5,813
South Carolina	24,225	24,117	108	23,517	100	600	....	....	8	689	618	1,270
Virginia	65,148	64,815	333	52,595	328	2,224	5	9,996	....	1,960	1,467	3,100
Washington	93,247	90,483	2,764	70,667	205	10,828	35	8,988	2,524	587	3,720	4,838
West Virginia	23,294	23,294	....	20,984	....	1,647	....	663	....	28	121	770
Wisconsin	180,073	179,611	462	170,305	337	3,646	125	5,660	....	87	3,711	5,403
All other states	260,574	254,911	5,663	247,288	4,468	1,825	625	5,798	570	1,495	7,644	9,284

[1] Includes states having less than 3 companies in order that the operations of individual companies may not be disclosed. These companies are distributed as follows: Arkansas, 2; California, 2; Colorado, 2; Connecticut, 2; Delaware, 1; Indiana, 2; Kansas, 1; Kentucky, 2; Louisiana, 1; Maryland, 1; Minnesota, 1; Montana, 1; Nebraska, 1; New Hampshire, 1; New Jersey, 2; Oregon, 1; Tennessee, 2.

[2] Includes 82 chemical.