SOME OF THE PROBLEMS OF ELECTRIC TRAIN LIGHTING.

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The use of electric light in transportation is no new thing. The first commercial plant sold by the Edison Company to be operated by outside parties was installed on the steamship Columbia in 1879 at Chester, Pa., and began operation in May, 1880. Another of the very early isolated plants was used for lighting the shops of the Manhattan Railroad, beginning in the fall of 1881. At about the same time a plant was installed in the Baldwin Locomotive Works. The first Edison central station started at Appleton, Wisconsin, about August 20, 1882, and the larger Pearl Street station in New York City started on September 4, 1882, were antedated nearly a year by the application of electric lights to a Pullman sleeper running between London and Brighton, England, in October, 1881. The latter had 12 small lamps supplied from 32 Faure cells. This was so successful that by December of the same year the whole train of eight cars was equipped with 29 Edison lamps of 9 to 10 candle-power, supplied from 80 cells of storage battery. An electric headlight operated by steam engine and dynamo mounted on the locomotive was used on the Kronprinz-Rudolf-Bahn on the night of March 19-20, 1881, and was followed in December of the same year by others in France. As early as 1879, Hinkefus and Wesel took out a German patent on a train lighting system in which a dynamo driven from the car axle operated incandescent lamps. Even before the Pearl Street station was in operation, the Pennsylvania Railroad began experimenting with incandescent lamps operated by storage batteries under the cars, importing Faure cells from

France in the spring of 1882, and installing them on a car in August of the same year. Although this experiment was not a conspicuous success, the company renewed its experiments in 1884, and in the following year began the regular operation of electric lighted cars. From this beginning, the company has continually increased its electrical equipment, until recently it has adopted the electric light as standard for all passenger service.

From the standpoint of the railroad men, the requirements for a system for train lighting are reliability, safety, freedom from features objectionable to passengers, cheapness in first cost and low cost of maintenance. All of these requirements are matters of degree. For absolute safety from fire and explosion, nothing can equal the incandescent electric lamp when installed and maintained in accordance with established practice. The voltages used on trains are invariably low and well within the limits of danger or even discomfort to persons who might by some unusual way come into contact with the conductors. That the service may be made reliable is attested by the fact that many cars provided with no auxiliary light whatever are in use on such roads as the Chicago, Milwaukee and St. Paul, which has been using electric lights since 1890. The Pennsylvania road, which was the first in America to experiment with electric lights for car lighting, is now equipping all of its cars west of Pittsburg with electric lights, and is reported to be throwing out all auxiliary lights. The incandescent electric light is free from the smoke, smell, vitiation of atmosphere and the possibility of fire and explosion common to all competitors, and it yields such a moderate amount of heat that it may be said to be absolutely free from features objectionable to passengers, except those of occasional dimness or of infrequent unsteadiness. Furthermore, the advantage of adaptability to local and decorative lighting, such as dining table or berth lighting, and the possibility of advertising tail transparencies, the convenience of electric fan ventilation and of electric heaters, make the electrically equipped train the choice of fastidious travelers. In the matter of cost, electric lights compare favorably with others when quality and quantity are considered.

The application of electricity to train lighting is now over twenty-one years old, and may be said to have reached its maturity. It has not ceased to develop and improve but it has reached the age of responsibility and reliability. Like other adults, it still meets problems to be solved and looks forward to a bright future.

All of the various systems of car lighting which have been put into practical application have adopted constant potential direct current as the only satisfactory source of supply. The voltage varies from 30 to 110. The number and strength of lights varies through wide limits, some advocating 10 to 80 8-candle lamps per car, or 80 to 600 40-candle-power per car, some cars having as high as 26 50-candle lamps or 1300 candle-power per car. Tests made by the writer in 1900 showed an illumination in different cars varying from 0.008 to 7.5 candle feet. The stronger illumination is not only more pleasing to patrons and a conspicuous advertising agency, but further the flood of light effectually masks ordinary variations due to imperfect regulation.

The various plans for the supply of power for electric lights on cars may be classified as battery, dynamo and combination. The dynamo may be driven by an independent engine in the baggage car or on the locomotive, or it may be driven from the car axle. It may supply the lights directly, it may charge storage batteries or may combine the two. The battery may be large enough to supply all the lights through a single run or through a round trip, it may carry all the lights for only a few hours, or it may carry only part of the lights a short time for occasional use. Each of the various systems meets its own problems of mechanical, electrical and financial natures.

Battery Troubles.—When a battery is used without any dynamo on the train, it should have sufficient capacity to carry the load through the entire run without falling below normal voltage, a difficult task on long winter nights without excessive weight. Fortunately, the greatest amount of light is usually required when the car first leaves the charging station and when its voltage is highest; as the battery gives up its charge, the load generally lessens, and allows the voltage to remain fairly constant through the night. When properly proportioned to the load, the performance is excellent. For example, some of the Pennsylvania cars running between Chicago and Jersey City and charged only at Chicago, make the round trip with 32 to 24 volts at start and with 30 volts upon return. As the cells become old, however, their capacity decreases, and the battery lighted cars sometimes give unsatisfactory service toward the end of the run. For trans-continental service the unaided storage battery seems impracticable. The short time allowable for charging at terminal stations often involves excessively high rates of charging, and rapid lowering of the electrolyte. The difficulty of close and

thorough inspection of cells often results in no inspection until failure is reported. The difficulty of allowing good ventilation of the battery boxes while keeping out the dust and other dirt, involves difficulty from low insulation and from decay of the battery trays and boxes. Injury to car body and to battery boxes is minimized by liberal use of insulating paint, but seems difficult to avoid entirely. The shaking of the cells incident to railway usage causes somewhat more rapid deterioration than in corresponding stationary service. Slopping of the electrolyte is avoided by using deep jars with or without covers; the space is so fully occupied by the elements that there is comparatively little liability to slopping except in case of unusually violent handling of the cars. The weight of battery, including boxes, etc., on a car with "full battery" equipment is about 3,000 pounds, which is not a very large proportion of the total 91,000 pounds weight of a coach or the 116,000 pounds weight of a sleeper. The first cost of about \$600 per car for "full battery" equipment, in addition to \$300 to \$400 for wiring, is not great in comparison with \$8,000 to \$10,000, the cost of a coach, or in comparison with \$16,000 to \$20,000, expended for a sleeper.

When the battery is charged during the run, there is more or less loss and deterioration due to the overcharging necessary to reduce the liability to failure on account of incomplete charging. The excessive charging and occasional over-discharging causes a more or less rapid deposition of mud at the bottom of the jars, which is liable to reach to the plates and so cause short-circuiting. The corrosion of connections due to the spray is frequently the cause of local action.

Engine Troubles.—On systems supplied from dynamos driven by steam engines, trouble is sometimes experienced from breaking of the flexible connection between the baggage car and the locomotive. It is common to use either the Moran ball-and-socket flexible joint or rubber hose strengthened by steel wire or expanded metal. The life of rubber hose varies from a few hours to several months. A blown-out hose can be renewed in a few minutes at the first stop of the train. There is sometimes trouble in disposing of the exhaust from the engine, which generally passes through the roof; when a good muffler is used, the grease is retained for the most part and is led through the bleeder through the car to the track, so that it is not carried back and deposited on windows and sides of cars. Sometimes in winter the condensed steam collects on the bellows of the car vestibules

to such an extent as actually to break the end of the car by the motion of the train. The reciprocating parts of the engines commonly used cause some vibration of the baggage car, which is transmitted through the couplings and may be felt to the extreme end of the train when in stations. The skill of the engineer in stopping the train is a large factor in the extent to which the vibration is felt through the train, it being least when there is a medium amount of slack. The adoption of the steam turbine may remove this difficulty. When the train is lighted from a dynamo and engine, some auxiliary source of light is necessary for the short intervals caused by changing locomotives, such relay being a storage battery or gas or oil lamps. The small engines use an excessive amount of steam per horse-power hour. The labor cost is not great; for example, on the Chicago, Milwaukee and St. Paul road each train on a run of 400 miles between Minneapolis and Chicago is allotted four baggage men who receive \$10.00 per month additional wages on account of attending to the electrical equipment, making a cost of \$1.33 for wages for 400 miles. On the Northern Pacific road, the baggage man has more than one man can handle, and an electrician goes with the train to attend to the engine and dynamo and to help the baggage man when necessary.

Axle System Troubles.—One of the greatest difficulties has been to secure satisfactory mechanical connection between the car axle and the dynamo. Gearing, belting and friction drives have been attempted with some degree of success. The latitude of motion of the car axle in three dimensions imposes upon the dynamo drive very difficult conditions. This with the difficulty encountered from the dirt and stones thrown up by the motion of the train and from the steam and snow or rain which may freeze upon the belt, imposes a problem whose satisfactory solution has required great ingenuity and expensive experimenting. That the axle systems are being adopted extensively is a triumph indeed. Direct gearing similar to that used in electric railway practice has attracted many minds, the danger from a hot box or defective gear on a railway train drawn by a locomotive of several hundred horse-power is a very different thing from a similar defect on a car moved by the geared motor itself, which is protected by fuses and circuit breakers. The next great trouble is the wide range of speeds met in train operation and the necessity for maintaining constant voltage from the time when the train is standing, through the point where the dynamo cuts in and

takes the load, to the highest speed attainable. The problem of regulation under such circumstances is one of no mean magnitude, and many are the ingenious plans proposed for its solution. Not only must the regulation take care of the varying speed of the train, but the battery voltage changes according to the state of charge, so that resistance or its equivalent must be inserted between the lamps and the dynamo or battery according to circumstances in order to keep the lamps at normal voltage. When one watches the operation of an axle lighting system which is so carefully designed and adjusted that no perceptible change occurs in the brightness of the lights between standstill and full speed, between the time when the battery is discharging and when it is charging, one can not but admire the success of the engineers in charge.

Financial Considerations.—All sorts of figures are given in connection with the cost of electric train lighting systems, some showing that each electric system is more expensive than any other, others showing that some particular electric system is the cheapest. The real cost varies greatly, according to the intelligence with which the whole plant is operated, this intelligence including both that of the engineer in immediate charge and that of officers of the road, who limit his facilities for proper handling of the equipment. In any case, the entire cost of maintaining the electric lighting system is a very small proportion of the entire cost of running the train, including not only the "operating expenses" but also that part of the general expenses chargeable to the particular train. The latter part of the cost, which is no inconsiderable part, is not usually obtainable. From the cost of operating the electric lights should be deducted the net profit from the added traffic which is attracted from other roads or which is created by the improved luxury of travel on electric lighted cars. These data are difficult, if not impossible to obtain with accuracy. If the added revenue created by the electric features of a train bears to the entire revenue from the train as great as or greater proportion than added cost of electric light, above other forms of light bears to the *entire* cost of running the train, then the electric light pays for itself.