ELECTRIC AUTOMOBILES.

BY ELMER A. SPERRY.

At the National Electric Light Association meeting a few days since, Mr. Crosby gave expression to a sentiment which has been rapidly taking form for the past twelve months. He said: "To-day we are as near sweeping the horses off the street with the automobile, as we were in 1889, in taking them off the tracks with the electric car."

Why, I ask, was the date '89 chosen? True, it marks a decade in the history of a branch of electrical application which has made the most stupendous strides; in fact, distanced all sober predictions as to achievement. It marks more. To those associated with the early development of electrical traction, it was about these years that the conservative engineer began to breathe easily; through rigorous experience that seemed nigh about interminable, he became convinced that at last, insulation and materials peculiar to the art, startlingly new to, and even held in derision by, the traction engineer, could nevertheless be relied upon to do the rugged work of heavy traction.

By '89, what we might call a "motor mortality" under severe conditions of service had been reached, that meant success. In a space then considered contracted, we had found room for ample area of journal and commutation; ample insulation and dielectric, to withstand the voltage strains. Methods of supporting and imbedding insulation and conductors had been devised, that ensured life not only against heat and overload, against vibration, pounding and concussion, and last, but not least, against misuse and abuse at the hands of the non-expert.

It had been an evolution, gradual though rapid; many had

contributed to its success; it had finally placed on a firm basis, the dream of the engineering world from the time of Watt, down; namely, "the rotary motor." The achievement can hardly be over-estimated. Unnumbered engineers had planned, toiled and passed with the solution of this enchanted problem almost within their grasp. A rotary motor with no oscillating or reciprocating part had at last been developed. It delivered torque, pure and simple—constant and regular, and had a capacity

Fig. 1.

measured by its size, and an efficiency measured by other motors, nothing short of wonderful. The motor was simply ideal.

At first, much was said to the effect that the machine was not a prime mover; but it had been "hitched to a star." Its system of connection with the prime source of power was at once so complete, and its association so intimate as to perform more acceptably and economically than the prime mover itself, and as compared with the smaller sources, its economy back to the fuel, even at miles distant, was found to be superior.

The fact that the electric motor is a rotary motor, contributes to the success of electric motor-driven systems to a degree diffi-

cult to over-estimate. Our compressed air friends, compelled as they are, to use a multiplicity of reciprocating engines as motors, have made a long step backward and are certainly in the rear in this, as in other features of their system.

The electric automobile coming upon the scene at this time

Fig 2.

falls heir to many of the rich results worked out in connection with tramway traction. There are many who go so far as to predict that the younger claimant will displace the former, especially the lighter class of street car service, and this doubtless will be the case to a degree.

Electric railways are rapidly reaching out with wider radii of operation and heavier and heavier equipment, and the automobile

will doubtless have wide use as supplemental to the heavier systems. In fact, co-operation has already been proposed in a number of instances. Its great flexibility and independence of track render it the ideal urban conveyance.

As the perfection of the electric motor gave the first impetus to electric tramway traction, so the point now reached in the perfection of the storage battery will yield equal results in the field of the electric automobile. The past three years have advanced the art remarkably, and drawn to it the attention of both skill and capital, and results have followed.

Fig 3.

The perfected storage battery presents some remarkable features. It even rivals the electric motor in its fitness and special adaptability to the automobile problem. Its very large reserve power at instant command ; its entire freedom from danger when fully charged ; its almost constant pressure throughout its capacity ; its recently developed capacity for quick charging ; and ease with which charge may be obtained in almost any hamlet in the country, are among its advantages.

The author can state definitely from personal tests of the principal types of batteries built on the Continent and in England that most of the published records are trustworthy as to specific capacity at the various rates. Some of the structures, however,

are open to serious objection from the standpoint of vehicular traffic. For instance, one of the most popular French batteries, though packed with the utmost care, reached this country with 50% of the positives broken off, and upwards of 40 fragments of positive plate disintegrated, per cell. What are we to expect with such a cell in the hands of the non-expert? Fortunately materials are at hand and systems of developing the plates perfected that render them thoroughly reliable and commercial to a degree commensurate with their life. The recent claim of one maker that batteries light enough for traction purposes would live through 5,000 full discharges is hardly credible, though the negatives of some special types seem to indicate a near approach to this figure. The engineer is at present engaged in increasing the

Fig. 4.

Fig. 5.

life of the light positive, with every indication of success, at least beyond the point ensuring commercial requirement.

It has been supposed that compressed air is the ideal stored power, but it is safe to say that electric storage distances it in the important features. Compressed air reservoirs weigh about 85 pounds per cubic foot capacity for air at 2,000 pounds pressure to the square inch, the air itself weighing nearly 11 pounds. How many horse power hours will this cubic foot develop? Those who know are reticent. It is found that by adding to the air a large quantity of heat, at extra cost, by compounding cylinders and using pressure reducers and wire-drawing valves, all with added weight, that about .27 of a horse power hour may be obtained. We know that this weight of storage battery will develop 1 1-2 horse power hours, requiring no reducing valves

and maintaining its pressure practically at one point until exhausted, rather than gradually exhausting the pressures, as with air. This straight line of discharge of the batteries is not matched by any other storage system of which we now have knowledge.

In common with other systems, the automobile has its limitations which are just beginning to be understood. These are, however, largely those of roadway and materials now employed. The fact that yielding tires are at present (practically) indispensable,

Fig. 6.

able, amounts to a tacit acknowledgment of the prevalent inferiority of roadway and pavements. The universal cry of the automobilist is for good roads, and no one improvement will do more to create a giant industry.

Should the pavements ever be so improved as to render the rubber tire unnecessary, would the steel tire do the work? The bearing of this question upon the heavier class of automobile drays, vans, etc., led the author to cause trials to be made touching this subject. Tests were made with a vehicle, having two

driving wheels, supplied with smooth, wide-faced steel tires, 72" in diameter, carrying 60% of load. The approximate draw-bar pull was ascertained on various kinds of pavement, dirt and gravel roads and macadam, on the level, and on grades, wet and dry. It was found that under the most adverse circumstances, ample adhesion could be relied upon for any conditions liable to be met. Soapy and greasy Belgian block pavement was found to give most trouble, but even here, 20% drawbar pull could easily be relied upon, with some, but not serious, slipping.

Fig. 7.

A lasting impression of the adhesion and value of smooth tires for road traction, is made by seeing a vehicle of this kind, ascending a 20 per cent. grade on an ordinary gravel road and rising easily, uphill over a 4" x 4" timber, placed in front of first one and then both the driving wheels, working as well on the wet portions as on dry.

The designer of the automobile is confronted with some practical problems which have not received attention at the hands of the railway engineer. For instance, in the simple matter of rendering the vehicle directible, and easily controlling the guiding

mechanism. Especially is this true in so arranging the parts that obstructions will not easily derange the mechanism or throw the vehicle out of its course. When one or the other of the guiding wheels encounters an obstruction of importance, the reaction works back to the guiding handle, tending to "whip" it out of the hand of the operator and throw the vehicle out of its course. (Recall the threshing of pole or thills in ordinary vehicles.) Many attempts have been made to reduce the leverage of reaction, but at best it has remained a problem of some importance.

Fig. 8.

The accompanying illustrations, Figs. 1 and 2, shows the method employed by the author. Tests designed to thoroughly demonstrate the practical operation of the device, and especially to compare it with the one ordinarily employed are illustrated in Figs. 3, 4, and 5. It was found that the amount of side-thrust transmitted to the guiding handle was practically in proportion to the leverage measured by the distance between the steering axis and the plane of the wheel, *at the height of the point of interception* of the obstruction. A 20" controlling handle was connected for equal angular movement with the swiveling axes, the wheels

being the same diameter, viz., 32" and loaded with the same weight, viz., 370 pounds. A small obstruction causes so flat a trajectory curve as to be negligible; this curve is seen at *x y* (Fig. 5). I have used, as the height of obstruction, the smallest dimension of an ordinary Belgian paving block, lying upon its side, assuming this to be the standard obstruction to be encountered by the various wheels in these tests. Operat-

Fig. 9.

Fig. 10.

ing the two devices each a number of times over this obstruction, at different speeds, a moment of effort upon the handle, tending to swing it laterally, or snatch it out of the grasp of the operator, was found to be in the two cases as follows:

Figure 4, ordinary device; mean value for pull = $10\frac{3}{4}$ lbs.

Figure 2, author's device; mean value for pull = 0 lbs.

This shows an entirely different action under practical operating conditions.

It will be seen from Figs. 2 and 3 that the steering axis is made to intersect the plane of the wheel well up from the bottom or ground line, where obstructions are encountered and where they may be met "head on," and therefore entirely neutralized, as has been demonstrated, giving no tendency to deflection of the wheel in either direction.

It is also found that the arrangement gives the vehicle a quality of self-centering, or running straight-forward, *hands off*.

Fig. 11.

This, as will readily be seen, is a natural result of the obliquity of the steering axes. The wheels, when turned, in the act of guiding, describe a conic section, the lowest point of which is the straight-forward running position. Another peculiar feature is, that in this action, each wheel is entirely independent of the other, throwing no stress either upon the connecting or guiding rods. Another excellent effect is the result upon the tires, the act of steering tending to describe a small arc, rather than the usual twisting of the tires. This can be especially noticed when the vehicle is standing still. Fig. 6 shows the inner wheel turned 45° .

This system of mounting the wheels is found to have peculiar advantages on rough roads and over obstructions, preventing entirely the reaction to the steering handle, giving entire immunity from fear of the controlling handle being suddenly wrested from the grasp of the operator; and on ordinary smooth pavements, instantly assuming the forward position, upon being "given the reins." This feature has been employed upon a number of vehicles both here and abroad, and is well received.

It is found with automobiles that while the best practice in

Fig. 12.

tramway traction can be followed closely in the main, yet the different conditions under which the vehicles operate, weight of motor permissible, height at which the motors are mounted, enormous variation in the rolling friction factor, and other points, allow of departures, which have an important bearing on the motor design and construction. For instance:—With the automobile, only a small motor is allowable. This should be light and yet should deliver all the power necessary in case of emergency. It is found practical to use a motor with a somewhat increased ratio of copper to iron, which should have a high overload capac-

ity, but more than all, it is found that the size and weight of the motor can be greatly reduced, if the gears can be practically compounded. This is especially desirable owing to the enormous variation in the rolling friction factor.

Obstructions and grades are encountered, never met on tram-tracks and at the same time may be coupled with soft road, which, owing to the weights necessarily present, would render progress impossible, unless an inordinately large motor were at hand. At such times, often if a few feet only can be compassed the journey can be resumed. It is under these and similar con-

Fig. 13.

ditions, that the value of the compound gear becomes apparent. One form of this gear, employed in a number of vehicles, has been found to be entirely satisfactory, increasing the leverage of the motor over the load. In case of a motor, with a suitable overload factor, this gear, while only doubling the leverage, is found to compass anything that has ever been encountered in city, park and country service. Any ratio of gearing can of course be employed. By means of the compound gear, the torque is brought up to nearly the slipping point of the drivers without overdraft of current-supply from the battery. The manipulation is by a small handle, usually imbedded in the cushion at the side, it being used only at infrequent intervals.

This lever attaches the upright arm seen in Figs. 7 and 8, the gear just being visible. This compound gear not only enables a small motor to meet an emergency, but has an important bearing upon the storage battery, acting as a safe-guard in a very important sense, preventing, as it does, inordinate over-drafts of electric current, and in this way, enabling lighter plates to be employed, without fear of "shedding" the active material. Another feature of importance in connection with the compound gear is found to be its interlock and interaction with the controller. This feature renders the compound gear entirely successful in the most incompetent hands. The gear cannot be thrown or changed, when the current is on, nor can the current be put on until the gear is entirely thrown to either one or the other of its normal operative positions. This is done automatically and without the knowledge of the operator.

Speaking again of the motor, as a whole, its elevated position and the comparatively open space it occupies, when compared with street car motors, enables the employment of ventilation. This should be designed with care, so as to prevent ingress of water and moisture. The ventilation is especially applicable to the small sized motor considering the heavy overloads to which they are frequently subjected.

In the hands of the non-expert, simplicity of control is found to be indispensable to satisfactory operation.

With the automobile, there is one handle, which always should be kept in hand, viz., the steering handle. The question naturally arises, "why not let this handle do all of the work of controlling the vehicle?" In a paper before this body, in 1894, the writer pointed out a system of tram car control, which has since been widely adopted, in which starting, stopping, speed control and brake were confined to the operation of a single handle. This having now been classed as the best practice with tram cars, why not utilize the combination in connection with the steering handle, allowing it, by the most natural and almost trivial movements, to do the whole work of operation. In this way, the entire control of the vehicle is simplified to a single handle. The direction of the vehicle is controlled by lateral movement of the lever, the vehicle going in any direction to which the handle is pointed or aimed. Depressing the handle, from notch to notch, increases the speed, and pulling up the handle, as one would draw in the reins, in case of

emergency, instantly turns off the current and applies powerful brakes. The intensity of the brakes is increased as the handle is further raised. When the speed has been reduced, by again lowering the handle, any of the speed notches can be readily picked up; the speed and brake being always under instant control, *one hand only being engaged*. It is apparent that the current manipulation to the motor and brakes requires only an imperceptible effort. In production, the controlling handle is made either to stay where placed, or is self-raising to the brake position, to suit the fancy of the owner. The controlling handle lying nearly horizontal, the "aiming" action in steering (see Fig. 6) completes the simplicity of the operation.

The controlling head, which is shown in Figs. 9 and 10 is supplied with an indicator showing at all times the position of controlling cylinder. Fig. 9 shows first speed and Fig. 10 the third speed, and by touching a button on the side (seen in Fig. 11) the handle may readily be raised to position shown in the figure, for convenience of occupants, especially for getting in and out on the driver's side.

In crowded thoroughfares, the brake is the most important feature of the automobile. The French authorities in passing upon vehicles, insist upon this factor more than any other, and it is certainly the most indispensable. Whatever else the vehicle can or cannot compass, it must be possible to stop it, and that instantly, on occasions. The brake should be powerful and at least in duplicate. The carriages illustrated herewith are each provided with three separate brake systems.

The location of the controller beneath the foot board (as seen in Fig. 11) is found to present decided advantages in point of convenient interlock and inter-connection with the brakes. The motor cannot be started without first removing all the brakes. This location gives ready access at all times and upon all sides by the hinged floor; gives a natural interlock between the controller and the compound gear above referred to, and also between the controller and charging terminals, which are also here located. Numerous accidents and even wrecks have been caused by failing to open a special motor switch, when placing the controller in series position for charging. A simple interlock, with the charging terminals entirely eliminates this danger, and indeed the interlocking system throughout the carriage very thoroughly protects it in inexperienced hands; for instance, if the directing indicator

(seen in Figs. 2 and 12) is removed, the motor and controller are locked. If the index or pointer of this indicator points forward the vehicle will go forward. If to the rear, the vehicle will go backward. If it points upward, (as seen in Figs. 6, 9 and 11) the carriage may be charged, but when in this position, all the conductors of the motor cable are automatically open-circuited, preventing accident. The pointer can never be manipulated until the controller is first open-circuited, and if the index is only partially turned, through carelessness, or otherwise, the controller cannot be operated until the mistake has been corrected.

The motor being light and small normally, should be of relatively "high speed," still farther reducing the weight. A small motor is possible with the compound gear. The double reduction motor possesses advantages of allowing the hand-brake to be operated on the intermediate shaft, thus working through the compensating gear. A small brake, in this way, gives all the leverage necessary, being one reduction back through steel gears with small peripheral velocity, thus acting without noise. Another advantage of double reduction is in keeping all the gears of the power system small, and thus ensuring a neater appearance. The somewhat higher speed permissible in the double reduction arrangement also renders possible the bipolar motor, with its higher efficiency, as compared with the multipolar. Every condition tending to higher efficiencies should be considered in connection with automobile equipment, as conserving the resources of the battery. These conditions are not as necessary with systems of tram traction, where the prime source of power is always available.

The location of the controller and current-manipulating switches low, (as seen in Fig. 11) and in front of the batteries, avoids hydrogen detonation and eliminates all danger of explosion from spark or opening circuit.

Much has been said of one motor versus two. This is largely a matter of mechanics; it is conceded that one motor gives higher efficiency than two of half the power, and is less expensive to maintain. As even the heaviest strains are comparatively small, the compensating gear, where one motor is employed, is easily maintained, yielding a combination which is far simpler and employs less parts than with a double motor equipment.

The automobile will, for some time, necessarily be in the hands of the inexperienced and non-expert, and while it is not

possible to render it "fool proof," yet certain safeguards may be employed in and about its operating devices and charging system, which will materially reduce and almost prevent derangement. The manipulation may be so thoroughly interlocked as to effectually prevent a wrong operation preceding the right one, and rendering it nearly impossible to make a mistake in anything like normal operation. Interlocks and safety devices are used in many branches of engineering; the introduction of automatic interlocking switches is a notable example, having placed steam railway operation on an entirely new basis. After subjecting these devices to continued practical test, and altering them until the requirements seem to have been met, the author is prepared to say that there is no reason why the important results reached in the interlocking switch and signal system, should not be compassed in automobile manipulation, and by devices vastly simpler and less expensive.

As to charging and care of batteries, it is believed that the differential watt-meter system for ordinary use, coupled with the periodic inspection by an expert from the home office or local headquarters, is the best arrangement now at our command. The author has found that the differential factor of the watt-meter should be adjustable, and should be brought from time to time into step with both the efficiency and charging curves of the battery. These curves change and are peculiarly altered by the time factors. These adjustments are easily made through determinations by the use of hydrometer. This can easily be one of the duties of the periodic inspection above referred to. The practical employment of the adjusting feature, or in fact, any device, by means of which the meter may be kept in step with the battery, is found to constitute such a meter an almost perfect safeguard against the destructive effects of overcharge and overdischarge in inexperienced hands. One tray of the batteries is shown in Fig. 13.

With the public conveyance, or a delivery system, operating a number of vehicles from one station, it may not be difficult to secure the services of a single expert attendant, yet for anything like commercial operation, the automobile itself must be entirely successful in the hands of the "raw recruit." Emphasis should be laid on the fact that the driver must be a man familiar, especially at first, with the routes and business in hand. The vehicle must be depended upon to perform successfully, even

under the most trying conditions, without demanding especial thought or attention on the part of its operator, who should simply be a good driver, and who, from an engineering standpoint, would be considered thoroughly non-expert.

DISCUSSION.

MR. HERMANN LEMP JR.:—The work of Mr. Sperry is well known. Yet it is well to know, that from personal information I have from Paris, his carriage was rated as A No. 1, and that in the land of the automobile.

Nor will it detract from his work if I say that of all automobile carriages to be built the electric carriage is the easiest. There is only one trouble: The storage battery. Our storage battery friends will say no, the trouble is everywhere else. In other carriages there may be a number of troubles but in the electric carriage there is only one; the storage battery.

Mr. Sperry has laid particular stress upon the value of a safe steering arrangement. I fully agree with him on that. The wheels of an automobile ought to be always locked completely and guarded against any strain from the road, and yet be practically free to be moved by the operator without any particular energy or skill on his part. We have operated a number of carriages by a hydraulic steering check, which need not be described at present.

I am rather surprised that Mr. Sperry should bring up the question of a change of gear. No doubt he has very good reasons for it, but I think he himself this morning made the plea for simplicity in apparatus, and if there is anything that recommends an electrical carriage or a steam carriage, it is that there is only one thing to operate and not two or three. While Mr. Sperry operates all by one lever, I do not think it is real simplicity because it means introducing a number of devices which are apt to give trouble. The electrical carriage in my opinion is paramount in success for its simplicity, consisting only of a battery, a motor, a controller and a brake.

Mr. Sperry seems to be in favor of one motor. I think that is a subject open for discussion. It is said a differential gives no trouble but I think it does. If one of the wheels slips it will at once cause the other wheel to lose traction as well, whereas if the two wheels may be independently moved, one may slip while the other will do the work of two. For that reason, when a single motor is used I would prefer a clutch arrangement. I don't think I have anything more to add on the subject but may communicate a few more remarks later on.

MR. C. W. RICE:—At page 494 Mr. Sever says the weight of the wagon complete is about one ton, so that the cost to run it is 18 cents per ton mile. Page 503, the weight two tons, and on page 506 he states it cost about five cents, that is two and