Thesis,

ELECTRICITY AS A MOTIVE POWER.

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ELECTRICITY AS A MOTIVE POWER

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Introduction.

While engaged in the preparation of a thesis on the subject of Electricity as a Motive Power I have been fully aware that the subject is more closely allied with the course of the student of Mechanical Engineering than with the Civil Engineering course, and that I was in consequence laboring at a disadvantage. In choosing the subject I thought to supplement my course of study by the investigation of a subject, a practical knowledge of which is eminently essential to the education of a Civil Engineer.

The discussion will be one of the applications of electricity, rather than of abstract theories and the investigation of principles. The latter are essential, and important, but do not belong in the department of Civil Engineering.
A glowing and eulogistic disquisition on the wonderful and unprecedented progress of the science of electricity, significant references to an "Electric Age", and a broad and imaginative speculation of the future possibilities of the "Subtle Fluid" would surely be in keeping with a Chapel Oration, though possibly not altogether appropriate in a technical student's thesis.

But that the science has rapidly developed is evident from the fact that books and articles treating the subject five or ten years old are already stale and behind the time. That the applications are of practical importance is demonstrated by the presence of a system of street lights and an electric railway in almost every city in the country of ten thousand or more population. But the mistake should not be made of supposing that Electricity is to take the place of all other power. The electric motor in no way reduces the demand on the steam engine, though it may be the means of supplanting the steam engine with other sources of power, as will be explained later.

Truly an electric current may be generated by other means than by mechanical motion, but not with sufficient economy to be of value as a source of motive power. Theories and investigations are on foot - one to generate a thermo-electric current by the direct rays of the sun; another to utilize carbon [ coal, coke, etc. ] in the common battery - that may, most probably will, eventually lead to a more economic production of elec-
thie power. At present the cheapest and almost universal method of generating an electric current for utilization as a motive power is by the transformation of mechanical energy to electric power by the electric dynamo.

The action of the electric dynamo depends on two important principles. The first, discovered about the beginning of the present century, that electricity can produce mechanical motion. The second, made by Faraday in 1831, that magnetic force is able to produce an electric current. For the transmission of motive power by the aid of dynamical electricity the following parts are necessary.


Electricity in no form or way creates power, but is a medium through which power can be transmitted or converted into more convenient forms. Any source of power may be used to operate the motor. Steam is of course the most common.

The electric dynamo involves the direct application of the second principle above mentioned i.e. that if a wire be rapidly vibrated between two magnets a current will be created in the wire. The strength of the current [electromotive force] varies as the length of the wire, and the strength of the magnet. The dynamo, as commonly constructed, consists of [a] two electric magnets consisting of cores of soft iron around which a current is passed through a coil of wire, the electric current imparting the magnetic property to the iron; [b] the armature, consisting of a coil mounted on a spindle and rapidly revolving between the magnets.
By means of wire brushes the two ends of the circuit are kept in contact with the two ends of the armature coil. The rotation of the armature creates a current in the armature coil, producing a difference of potential in the two ends of the circuit. To this difference of potential is due the current in the circuit.

The circuit is the conductor used for transmitting the current from the dynamo to the motor, usually a copper wire. In the direct current the coil around the magnets are usually joined in the circuit, the magnet and the circuit strengthening each other by a reciprocal action. In the alternating system the magnet coil receives its current from a small and independent direct current machine called an exciter, in order that any accident to the magnetic coil may not disable the dynamo.

The principles involved in the construction of the motor are the same as in the dynamo, the application being exactly the reverse. An electric current is supplied to the armature by the circuit, and causes rotation of the armature. The power stored in the rotation of the armature is transmitted by mechanical gearing to drive wheels or other points as desired.

The present use of electricity as a motive power is in the main limited to the use of street railways. For this purpose it can be stated specifically and certainly that it is beyond the experimental stage in the sense that it can be and is used at a less cost and with a much greater speed than is attainable with horse power. Electric railways are divided into two general classes according to the manner of supplying the power, called: [1] Transport of Force Rys. [2] Storage Battery Rys.
Electric Railways of the first class are those in which the current generated by the dynamo is transmitted directly to the motor on the car by means of a circuit along the track. These are of several sub-classes distinguished by the different methods of transmitting the current. The most common are: [a] The Overhead System, in which the conductors are supported by a line of poles. A very large proportion of the electric roads now in use are of this type. It is in most cases the least expensive method, and is the one that generally supercedes the horse-car in small cities, and on suburban roads. The connection between the car and the line is made by a trolley attachment to the car and running along on or under the wire. The use of this type is not advantageous on the principal streets of large cities for the reason that the poles and lines are too great an obstruction to the street. [b] The second type of this class are the surface conductors. In this type the current either reaches the car through a center rail and returns through the rails the wheels run on, or the lead is through one rail and the return through the other. In the latter case the wheels have to be insulated from each other. This type dispenses with the objectionable poles and wires, but is defective for the reason that it leaves the uninsulated conductors exposed to persons and animals crossing the track. In consequence the electromotive force has to be kept down to about 150 volts which materially increases the cost of running expenses. [c] Under-ground Conductors are those in which the conductors are enclosed in a conduit, connection between the car and conductor being made through a slot under the center of the track. This type is free from the most objectionable features of the two above de-
scribed. - Pole and wire system, and exposed conductors - but is enormously expensive, both in original cost and in maintenance. The latter due to leakage of electricity, and cost of removing water and filth that find their way through the slot. The cost of the necessary conduit is about $20,000 per mile. A combination method of running the lead current through an overhead wire and the return current through a surface wire protected by being placed under one of the rails is sometimes used.

If two strips of lead [Many other metals will answer, though not so well] immersed in dilute sulphuric acid be joined in an electric current, oxygen will be liberated at the positive electrode, forming on the plate peroxide of lead, and at the magnetic electrode free hydrogen will accumulate on the plate. If now the circuit be broken and electric will take place in the opposite direction, restoring the acid and lead to their original forms. This is the principle of the "Accumulator," "Secondary Battery", or "Storage Battery". A common and convenient form is to roll two thin sheets of lead together, keeping them from actual contact by narrow strips of felt, and immersing them in cylindrical jars of acid. Each jar constituting one "cell". The object is to expose a large surface of lead to the action of the acid with as little bulk and weight as possible. For running the the ordinary two horse cars from 80 to 100 cells are commonly used, weighing from 30 lbs. to 40 lbs. each. 800 lbs. would be a reasonable estimate for the weight of the motor and gearing connecting it with the axle, giving the car an additional dead weight of perhaps 4,000 lbs. If the weight is too great for four wheels eight may be used with two swinging trucks. The charging of the cells is done by a dynamo.
run by steam or other power. Such a battery capable of doing four hours
work may be charged in four hours by a dynamo run by an engine of ten H.P.
Estimating the cost of one horse-power-engine at one cent, the cost of
power for one day of sixteen hours would be 10×10×$1.80. Such cars would
make from seven to nine miles per hour; one third to one half more than
cars run by horse power. The advantages of the storage battery system are
[1] Neither the expensive conduit nor the objectionable and unsightly line
of poles are required, and the car is rendered perfectly independent so
that it can be run on any track. [2] Only the power needed is consumed.
If the seats are not all filled the car will run farther in consequence.
[3] The electricity, besides running the motor, may be utilized [a] to
supply the car with incandescent light [b] to operate a signal gong and
electric bell for the use of the conductor [c] to stop the car in case of
danger or accident, which could be done very quickly by reversing the
motor.

The disadvantages of the storage battery system are: [1] extra
dead weight. In cars as commonly constructed about two tons. [2] Lack of
efficiency in the batteries. The highest claimed is about 92%. The ef­
ficiency actually obtained in practice is stated by many authorities at
about 70%. [3] The storage batteries cannot be operated on high grades,
[5' or 6'} the common limit ] as the power required makes too great a de­
mand on the batteries. The tractive strength of the motor is commonly a­
bout five horse power. [4] Cost of plant and maintenance. The cost of two
sets of batteries is about $3,000. Makers of batteries offer to guarantee
them good for two years, and the plates of lead oxide still possess some
value after they are unserviceable, as the lead can be reclaimed from the oxygen and cast into new plates.

An article published in Le. Genie Civil makes the following comparison of efficiency, or economy of power of the Storage Battery, and the Transport of Power system.


Assume the power developed by the engine at 100%. Assume further.

[1] Efficiency of dynamo at 70%
[2] Efficiency of battery at 70%
[3] Efficiency of motor and gearing at 72%

The net efficiency of the system will equal .70 x .70 x .72 = 35.3.


Assuming, as before, the efficiency of the engine at 100% and

[1] Efficiency of dynamo at 70%
[2] Efficiency of circuit at 60%
[3] Efficiency of motor and gearing at 72%

The net efficiency of the system will equal .70 x .60 x .72 = 30%.

The above figures show an apparent advantage of about five percent in favor of the Accumulator system, but take no account of the extra weight of the accumulator car.

Assuming the weight of the storage battery at 4,000 lbs, and the total weight of the car and passengers at 9,500 lbs. the efficiency of the Storage Battery system will not be 35% but about 22%, showing an advantage of about 8% in favor of the Transport system. The assumptions, however, are so uncertain as to make the figures of little or no value.

William Wharton Jr. estimates that three electric cars will do the work of four horse cars, and makes the following cost of running expenses for one year.*


Four conductors at $3.00 each per day of sixteen hours $4,380
Four drivers at $2.50 per day of sixteen hours each $3,350
Thirty-six horses at $.50 each per day $3,570
One year's deterioration of four cars at $200 each $ 800
One year's deterioration of thirty-six horses at $40 each $1,440

Total $16,840


Three conductors at $3.00 per day of sixteen hours $3,285
Three drivers at $2.50 each per day of sixteen hours $2,737
Electricity at $2.00 per car per day $3,285
One year's deterioration of three cars including motor and other appliances $4,800

Total $13,012

These figures show an advantage of $3,800 in favor of the electric car.

Present indications are not favorable for the adoption of electricity as the motive power on railroads in general. The tractive power required of a locomotive would be too great a demand on a storage battery, and the well known laws of resistance of conductors—proportional to the square of the distance, and inversely as the area of the section—

* See Railroad Gazette, March 27, 1880.
render the use of long distance currents disadvantageous. A plan has been suggested of dividing a line into sections of about thirty miles each, and locating a dynamo at the middle of each section, thus reducing the distance from the dynamo to the most distant points of the circuit to about fifteen miles.* With no.0 copper wire the efficiency at the ends of the circuit is estimated 75%, the average efficiency at 85%, and the net efficiency at 30%.

The advantages of an electric system would be:-

[2] A less number of employes would be required.
[3] The speed might be increased.
[4] A lighter locomotive might be used.

The latter proposition is based on the assumption that an electric current adds to the adhesion of the wheel to the rail. This is generally conceded to be true, but few experiments have been made to determine the amount.

The problem of vital importance now awaiting solution is the discovery of a method by which a current may be transmitted long distances without great expense, or loss of electromotive force. If such a method can be devised the numerous predictions of "An Electric Age" will be literally fulfilled, and the steam engine will be discarded, as there is abundant natural power stored in the water courses of the country to supply all its demands. According to the United States Lake Survey the water power of Niagara alone is seven million H. P.

* See Railroad Gazette - March, 21 1890.
The recently organized Niagara Falls Power Co. have the project in view of supplying power to Buffalo and other neighboring cities by electric transmission. They estimate that power can be profitably furnished by turbine wheels at ten dollars per horse power per year on the ground. Generated by steam it costs from $20 to $90 per horse power per year. The latter equals one cent per H. P. hour.

Circuits twenty five to thirty miles in length are not infrequent in electric light systems.