miles, to a receiving basin in Germantown, the surface of which might be 240 feet above the city datum, and the water surface nearly 249 feet above the city datum, or 254 feet above mean tide in the Delaware. In the first 10½ miles of its course the proposed aqueduct crosses a number of important tributaries to the Perkiomen, which rise in the hills di viding the waters of the Delaware from those of the Schuylkill in Montgomery and Bucks counties, more than 500 feet above tide. It is a part of the plan to make these streams tributary to the water supply by the erection of impounding dams upon them.

The area of the watershed of the Perkiomen above Green Lane, and the tributaries crossed by the aqueduct, is not less than 200 square miles, with a rainfall capable of affording about a hundred thousand million gallons a year.

The advantages of the proposed plan include the following· It will supply from a single point more water than is required for the present population of the city, and will deliver the water to a basin 27 feet above the highest reservoir in the city (Belmont), and from 104 to 145 feet above the other existing basins. It can supply Roxborough and Mount Airy basins by a pumping station at the aqueduct, near the former basin, and save more than 200 feet in the lift encountered at the present Roxborough pumping works. It will obviate the necessity for all the present steam pumping stations, with their expensive and often troublesome monster pumps, and leave Fairmount and its water power, when disconnected from the basins, to be run moderately in the summer to feed lakes and fountains in the park or in flushing main sewers.

The estimated cost of the work is less than that of the Croton Aqueduct; and as the full capacity of the aqueduct will not be required for many years, a large part of the work can be delayed until the city will be easily able to bear the burden.

EDISON'S ELECTRICAL GENERATOR.

BY CHARLES A. SEELEY, PH D.

Electric machines convert mechanical into electrical energy. The obtaining of electricity may be considered a manufacturing process, wherein steam power is the raw material and electricity the product. The best machine, other things being equal, will give the greatest yield of finished product from a given expenditure or consumption of raw material. The ratio of yield to consumption is the expression of the efficiency of the machine.

How many foot pounds of electricity can be got out of 100 foot pounds of mechanical energy? Certainly not more than 100; certainly less. What are the sources of loss, and what become of the lost foot pounds? Friction and resistance of the air inexorably demand their share in all kinds of machines. In the electric machine a heavy armature, sometimes spread out like a fanning mill, must be revolved at the rate of 500 to 1,000 times in a minute. Also there are great leakages incidental and peculiar to the electric machine, which may be summed up in the expression local actions, which consist in currents induced outside of the normal circuit, changes in the magnetism of the magnet cores, etc. How many foot pounds do we lose or are we obliged to lose out of the 100 expended? How many foot pounds of electricity are left after deducting the losses? The facts and laws of physics, with the assistance of mathematical logic, never fail to furnish precious answers to such questions. People generally, however, are not familiar with the methods and language of exact science, and prefer results of direct, plain, actual, and practical experiments, results unmixed with any abstraction. We appeal now to the testimony of such experiments.

In 1877 a committee of the Franklin Institute, consisting of ten competent and eminent experts, with a view of determining the capabilities of electrical generators, made a series of trials with the best machines then procurable. Their elaborate report describing the details of experiments was published in the May and June numbers of the Institute *Journal* of 1878. This report has become a recognized authority, and remains, so far as I know, in all respects unimpeached; and I shall use it now with fullest confidence in the accuracy of its statements. The committee experimented with 6 machines: 3 Brush, 2 Wallace, 1 Gramme. To suit my present purpose I have reduced statements of the report to the simple symmetrical form of the table below. This table shows the losses and produce of 100 foot pounds of power delivered upon each machine; the figures may be read as representing foot pounds or per cents.

1.	2	3	4	5	6
a. Brush	16·7	33 5	50 1	50·	31·
b. "	10·4	50 9	61·1	39·	22·
c. "	11·1	41·	52·1	47·	27·
d. Wallace..........	8·	53·2	58·2	38·1	14·
e. "	8 6	63	71·6	30·3	12·
f. Gramme	7 4	21·	28·4	71·2	38·

1. Names of machines.
2. Friction and resistance of the air.
3. Local actions, including all losses, except those of 2.
4. Total losses, the sum of 2 and 3.
5. Total current of the normal circuit, or the total yield of electricity.
6. The electricity utilized in producing light. It is substantially the amount utilizable for any purpose.

I present this table as worthy of thoughtful attention; it should interest all electricians. The facts which a little study will disclose may prove somewhat appalling to those whose imaginations have been busy with bringing Niagara power to New York and with the demolition of gas companies.

The facts shown in columns 5 and 6 are worthy of special attention. The total produce of electricity is shown in 5, and in 6 the practical value of that electricity; the figures in 6 are only about one-half the corresponding figures of 5. Why is it that when we have produced the electricity half of it must slip away? Some persons will be content if they are told simply that it is a way which electricity has of behaving. But there is a satisfactory, rationa. explanation, which, I believe, can be made plain to persons of ordinary intelligence. It ought to be known to all those who are making or using machines. I am grieved to observe that many persons who talk and write glibly about electricity do not understand it; some even ignore or deny the fact to be explained. I will try to set forth the case plainly.

Electricity moves in a circuit, and in moving disappears; that is, it is converted into some other form of energy. The same electricity does not move round and round again; it never repasses the starting point; it does not exist to repass the starting point. As it moves it falls and dies in its tracks, and its dead body at once and on the spot is resurrected, but in a changed form. Now a part of the circuit is always and of necessity inside of the machine or battery; it is the wire of the armature or the liquids and the metals of the battery. This part of the circuit also is inaccessible, and the electricity which is here transformed is unavailable; this electricity, in fact, is worse than useless, for the heat into which it is transformed is one of the serious practical difficulties of the machine. It is then only the electricity which appears in the circuit outside of the machine which is utilizable.

At this point plausibly comes in a suggestion that the internal part of the circuit be made very small and the external part very large. Why not (say) make the internal part 1 and the external 9, thus saving $\frac{9}{10}$ and losing only $\frac{1}{10}$? Unfortunately the suggestion is not practical; a fallacy is concealed in it.

The electricity is truly converted throughout the entire circuit, but not evenly in proportion to the length of the circuit. The conversion takes place precisely and exactly in accord with the resistance in the circuit to the flow of the electricity. The electricity may be considered as distributed over the whole circuit *pari passu* with the resistance, and thereupon is transformed into energy of another name, distributed as to the quantity precisely as was the electricity. This explanation does not disclose the weakness of the suggestion, but it will assist us in finding it.

Beasts of burden and other rational creatures redouble their efforts when their burdens are increased, and "thrice is he armed," etc. Electricity behaves very differently; there are no moral suasions or reserved forces behind it. Increase its burden, and it weakens right down; it is more stubborn than a mule; it won't budge at all, except after its narrow plan. The law of the electric current is that it exists or is produced *inversely* as the resistance to its flow in the circuit; double the resistance and the current is halved; treble the resistance and the current is one-third, etc. In any machine let the armature revolve steadily, and the current produced will depend solely upon the resistance; with the least resistance you get the maximum current, with the greatest resistance you have the minimum current. Now, also, the internal resistance of any machine is constant or unalterable. In order to get any external effect, external resistance must be added to the internal. To get the greatest yield from a machine or battery, it must be short circuited; that is, the external resistance must be suppressed; but then you find yourself in the interesting predicament that all the electricity is securely bottled up in the armature and is of no good to you. On the other hand, arrange things so that the greatest part of the resistance is external, and the electricity has shriveled up to a quantity which is utterly useless to any allopath. There is evidently a just mean; what is it? What is the best practical ratio of the external and internal resistance? The mathematical calculations which clearly and beautifully answer this question, and which take in the principle that the sum of variables is least when they are equal, are probably beyond the experience of the average reader, and I substitute a sort of cut and try method.

Let the current of the short circuited machine be (say) 100. Now add an external resistance (R″) equal to the internal (r), thereby making a doubled total resistance (R). (r + R′ = R). The total current has become 50, and the external or utilizable part of it is 25. Treble the R, making r = 1 and R′ = 2, and the total current becomes 33⅓ and the utilizable part 22·2. For another trial, make external half as great as internal r = 1, and R′ = ½, and total current becomes 66·6, of which 22·2 is utilizable. Now we are getting indications of the fact that the greatest external current is produced *in a given time* when the external and internal resistances are equal. I recommend the reader who is not yet satisfied to continue the cut and try plan till he shall be.

But, exclaims the bright scholar who is always on the *qui vive* for flaws, it is a question of economy, and it may be best to take a little more than the given time, and so get a greater portion than the half for our use; time is cheaper than coal; or, if we must have a certain great quantity of electricity in a short time, we may build a very big machine or use a good many little ones; why not save nine-tenths of the total current? The remarks of the bright scholar are always entertaining, sometimes they are instructive. The trouble with him is that although his vision is very clear it is not so wide; he is quick to spy out a thing, but he does not observe its environments. Why not nine-tenths? It is a hard thing to do after perusing the table of results above given; but consider or imagine that the losses of a machine by friction and local action are reduced to one-tenth, so that 100 foot pounds of steam power produce 90 foot pounds of current, of which the external part of the circuit (= to the internal) shall have 45. Now adjust external resistance so that you shall get $\frac{9}{10}$ outside and $\frac{1}{10}$ inside, and weigh and figure up the results. Instead of getting 9 for 10 invested, you have 16·2 avails of 28 invested, or at the rate of 5·8 from 10 invested. There is a clear gain by attending to the spigot, but the steady leakage at the bung was still going on. I do not mean to say that the equalizing r and R′ should be an inflexible practical rule, but simply that the advantages of varying from it are not so great as some persons suppose; also the loss from local action is not constant for varying products of electricity; the illustration ought not to mislead any one, and the precise data for determining the peculiar ratio of r to R′ for the most economical working are plainly enough indicated.

Now, on looking over the above I feel as if I had led the reader over a wearisome roundabout road, when there is a short cut across lots to the destination. My excuse is that the short cut is not a familiar thoroughfare, and the average traveler cannot feel confidence in it. Mathematics is what I have in mind. To the mathematician the expression $a^2+b^2=c^2$ is the clear expression of the relation of the sides of right-angled triangles and many other things, but we plain people whittle up a great many shingles or pencils in the cut and try plan before we can apprehend the thing it teaches.

But there is one little expression, simple in form, yet full of meaning, in fact a mine of the elements of ideas on electricity, which I would, if I had my way about it, compel the reader to wrestle with till he had completely mastered it. It is the expression of the principal facts about the electric circuit; it is called Ohm's law, and it is this: $C=\frac{E}{R}$. C is the strength of the current, that is, the quantity (say ft. lb.) flowing per second. E is electromotive force, an idea corresponding to tension, pressure, or head. R is resistance to the flow. (It will assist the tyro to observe that electricity has some of the properties of ordinary fluids, and that Ohm's law is true for water and steam. Let, for example, C be galls. of water per minute, E head of water, R resistance to flow, narrowness of pipes, friction, etc. The formula, however, is not useful outside of electricity, mainly for the reason of the difficulty of specifying and keeping constant the elements which constitute R.) The formula declares that C varies directly with E, and inversely with R. In any machine E varies with velocity; when the velocity is uniform E is constant, whatever be the ratio of external and internal resistance, or whatever be the produce of the machine in usable current. If it is desired to distinguish the internal (r) from the external (R′) resistance, r+R′ may be substituted for R, when $C=\frac{E}{r+R'}$. In any machine r is always constant, and E is constant for constant velocity; in this last case C can vary only with R′. C represents only the total C of the normal circuit; the useful C, or that which can appear as light, heat, chemical or mechanical energy outside of the machine, $=\frac{C(r+R')}{R}$ etc., etc.

But about Edison's electric generator! The articles about it on pages 242 and 272 are the texts on which I have discoursed, and although I have not named the generator, it has all the time been in mind. Those who are accustomed to read between the lines, have some of my thoughts which are not yet put on paper. But lest any one should suppose that I am unfriendly to Mr. Edison and his work, I hasten to say that I am fully in accord and sympathy with the writer of page 242, when he asserts and laments that the newspaper reports of the sayings and doings of Mr. Edison were exaggerated and inaccurate, and consequently damaging to him. No one capable of making the improvements in the telegraph and telephone, for which we are indebted to Mr. Edison, could be other than an accomplished electrician. His reputation as a scientist, indeed, is smirched by the newspaper exaggerations, and no doubt he will be more careful in future. But there is a danger nearer home, indeed among his own friends, and in his very household. The lamentable case of Deacon Richard Smith and his wicked partners should serve as a warning. It is said that the Deacon was wise and good until his wicked partners got control of him, when he behaved foolishly and uttered blank nonsense. The writer of page 242 is probably a friend of Mr. Edison, but possibly, alas! a wicked partner. Why does he say such things as these: " Mr. Edison claims that he realizes 90 per cent of the power applied to this machine in external work;" "The economy of this machine is shown by the fact that one man may turn it with sufficient rapidity to maintain the electric arc of a Jablochkoff candle, etc." Perhaps the writer is a humorist, and had in his mind Col. Sellers, Indian trader foot pounds, etc., which he could not keep out of a serious discussion; but such jests are not good.

Mr. Edison has built a very interesting machine, and he has the opportunity of making a valuable contribution to the electrical arts by furnishing authentic accounts of its capabilities.

New York, October 30, 1879.