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OF CANADA

OFFICIAL PROCEEDINGS

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PROCEEDINGS OF THE CENTRAL RAILWAY AND ENGINEERING CLUB OF CANADA.

COURT ROOM NO. 2, TEMPLE BUILDING,

TORONTO, September 22nd, 1912.

The President, Mr. J. Bannon, occupied the chair.

Chairman,—

This being the opening meeting of the fall session the Executive Committee decided to vary the usual proceedings by having this an open meeting.

Mr. E. C. Adams, of Detroit, has kindly consented to come here and entertain us. Many of you do not need an introduction to Mr. Adams, having met him at previous meetings of the Club, but to those who have not met Mr. Adams, I would say that he is an old and valued member of the Club, ever ready to do anything in his power for the welfare of the Club.

The object of the Executive and myself in having a meeting of this kind at this time, is to give the old and new members an opportunity to get acquainted, which will, no doubt, be to their mutual advantage and also assist the Club in its work.

One of the aims of the Club, is to give members an opportunity to exchange ideas on topics of interest to themselves and such an occasion is seldom afforded at our regular meetings, the time being fully occupied reading and discussing the papers, consequently we thought that the members would welcome an opportunity to get in closer touch with each other.

The paper for the evening is on "Everyday Electrical Terms and Their Meanings," by Mr. J. W. Helps, Power Engineer, Toronto, and those of you who had the pleasure of hearing Mr. Helps read a paper a few months ago will remember the very able manner in which he dealt with his subject, and when you get the September number of the JOURNAL, I am sure you will read with great interest Mr. Helps' remarks on this subject, as from my experience with Mr. Helps, I can safely say that what he undertakes to do will be done well.

I will not detain you further with my remarks, as I am quite sure you are all anxious to see what Mr. Adams has to offer you.

Mr. Adams entertained the members for an hour and a half, songs at intervals being given by Mr. Slack and Mr. Brazil.

A hearty vote of thanks was accorded Mr. Adams by the members present for his excellent entertainment.

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SOME EVERY DAY ELECTRICAL TERMS—AND WHAT THEY MEAN.

When considering the preparation of this paper, there were some difficulties which seemed to stand in the way. The first was, that it seemed somewhat superfluous. It certainly did seem to me to be something like school talk to attempt a graphic interpretation of the more common place electrical terms, because to so many the meaning of these would be well known. But neither the esteemed president, or our worthy secretary would permit of my getting out on that score. They argue that whilst there are a few who know it all, there are some who don't. Very well: this paper then will be, not for the man who knows it all, but for the other fellow.

Another difficulty however, presented itself: What to select as terms needing explanation? It is morally sure that any such attempts will fail to cover the very things that someone wants to know. To this your secretary has replied, not only giving me wide discretionary powers, but also asking me not to limit my remarks too strictly to the actual subject described in the announcement.

One other consideration that suggested itself was the fact that so much popular stuff has been written and published at cheap figures dealing with this very subject, making this paper seem unnecessary. In order to prove this, and to see what kind of stuff was being served up, I bought a book which is declared, in its preface, to be "a practical handbook of reference so clear and lucid in its definitions that it is a work of the highest educational merit and can be studied alike by the expert and the subordinate worker."

That sounds good, does it not? It did sound good to me. But ——! Let us look at a few of the "definitions."

"Ampere—The accepted unit of electric current. A flow of electricity at a rate which transmits one Coulomb per second."

"Alternating Currents—Currents which alternate."
"Battery—A term often applied to an electric battery."
"Continuous Current Motor—A motor worked by continuous current."

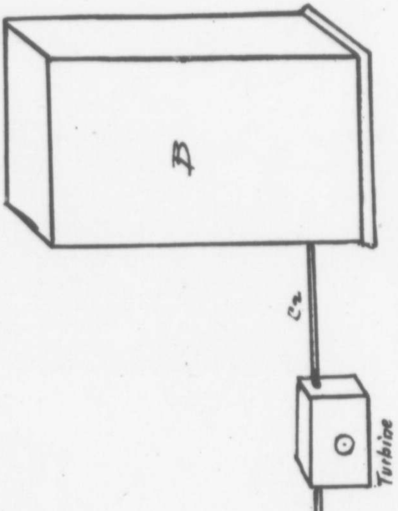


FIG. 1.

"Dynamo—A dynamo-electric machine."
"Field Regulating Box—A resistance box."
"Field Rheostat—A field regulating box."
"Static Discharge—Disruptive discharge."

"Track Bond—A rail bond."

"Voltage—Potential difference or electro motive force expressed in volts."

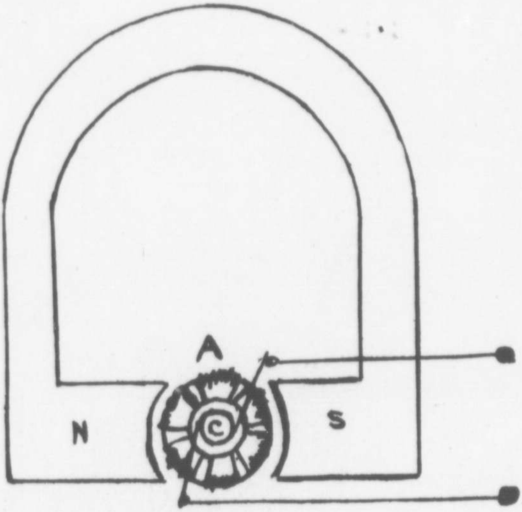


FIG. 2.

Of course one is prepared to admit at once that these "definitions" are very "clear and lucid"(?) Many of them in fact are not even correct, although they may be amusing. But it makes it quite permissible to give some little talk to the man

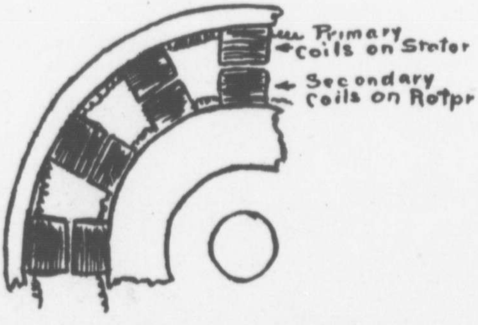


FIG. 3—Section of A. C. Generator.

who wants to get a comprehensive idea as to the real meaning of the terms he is meeting every day.

The points I have selected for consideration are:

Amperes, Ohms, Volts, Watts, Kilowatts and Kilowatt hours.
Why a fuse "blows" or a wire "burns out."
The electric circuit.
"Positive" and "Negative."
"Voltage drop on line" or "line loss."
"Transformer."
"Alternating."
"Phase"—"single phase" and "three phase."
"Cycle" or "Frequency."
"Induction motors."
"Stator" and "rotor."
"Squirrel cage rotor."
"Motor efficiency."

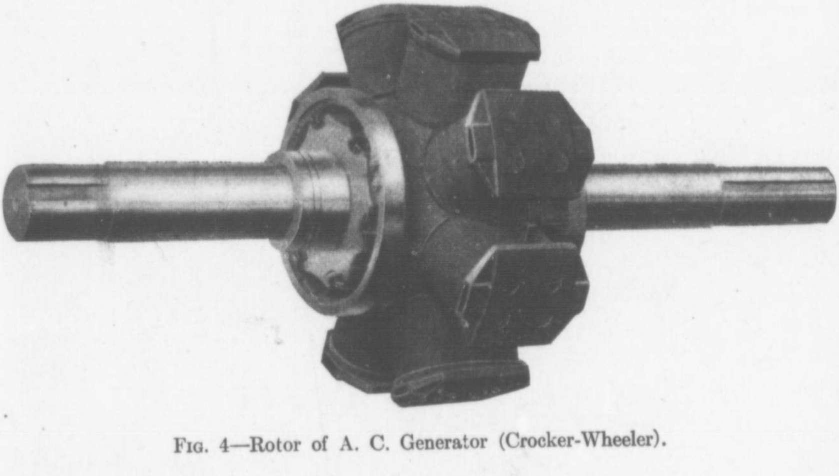


FIG. 4—Rotor of A. C. Generator (Crocker-Wheeler).

Perhaps the three most familiar terms are Watts, Amperes, and Volts, remembering at once that the term "kilo" is simply 1,000, hence a "kilowatt" is 1,000 watts. We will take these three first.

In the first place the term "watt" is not purely and simply an electrical term, though generally used in that connection. It is really *a unit of work or energy*. Just as the gallon or the litre each expresses some quantity in volume, so the watt or the horse power expresses some unit in work done. Although not customary, it would be scientifically correct to speak of a gas or steam engine as having so many kilowatts capacity instead of horse power capacity. The watt or kilowatt is not, therefore, a measure of the quantity of electricty, but of the work done. It gives greater flexibility than the more familiar "horse power" unit. For instance, you could speak of "10 watts" or "$\frac{10}{746}$ of one horse power" and both would mean the same. Now, suppose we are asked how much it will cost to run an engine doing 25 h.p. of actual work? We immediately want to know, for how long? So the factor of time comes into play, and the energy in kilowatts expended multiplied by the number of hours gives an amount in kilowatt-hours.

Why then is the kilowatt-hour taken as a unit-factor in the charges made for electricty? The charge made is for electrical energy expended, and it takes a certain combination to produce certain results. The electricity is the means by which power is transmitted. Imagine a huge belt connecting the pulley of a turbine at Niagara Falls with a huge pulley here in Toronto. That belt is not there, but the electricity takes its place. And the power which drives the turbine is really the power which operates the machinery in Toronto. A little consideraction of this will make it quite clear that the kilowatt-hour alone is not a fair basis for payment, hence the popularity of the so-called "scientific" method of rate making by power supply concerns, including the Toronto Hydro-Electric System.

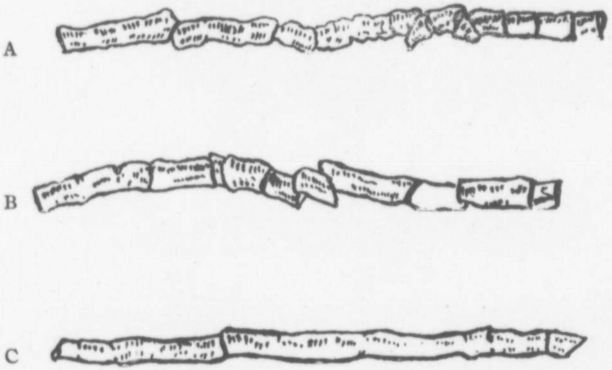


FIG. 5.—Magnified view of burnt-out "Tantallum" filament. A, 60 cycle, 150 hours; B, 130 cycle, 300 hours; C, 25 cycle, 467 hours.

But what's watt? The watt is the product of the amperes, multiplied by the volts. So we will proceed to discuss these two terms next.

Suppose we turn from electricity and for purposes of illustration we take something more tangible—say compressed air. We will suppose further that we have a length of pipe free from bends or anything else that will cause friction loss—in fact, with 100 per cent. transmission efficiency. Now we find that pipe is filled with air at a density of 2 atmospheres; also that the air is travelling through the pipe at the rate of 2000 ft. per minute. Now, there will be, at the delivery end of that pipe, a certain force. From the density of the air we get a certain pressure. Taking the area of the pipe to be 10 sq. inches, we will have a total pressure of say $10 \times 30 = 300$ lbs., we have then a weight of 300 lbs. moving at the rate of 2000 ft. per minute, giving us, in horse power, $\frac{300 \times 2000}{33000} = 18.2$ horse power approximately. The ampere is the unit of *electrical density*, corresponding to the density (2 atmospheres) in

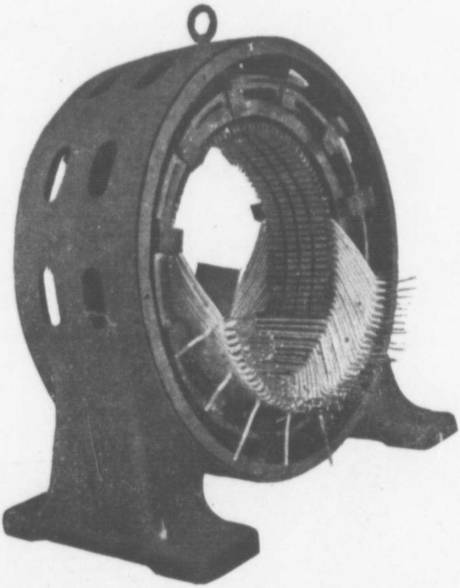


FIG. 6—Stator of a Wagner Motor during winding.

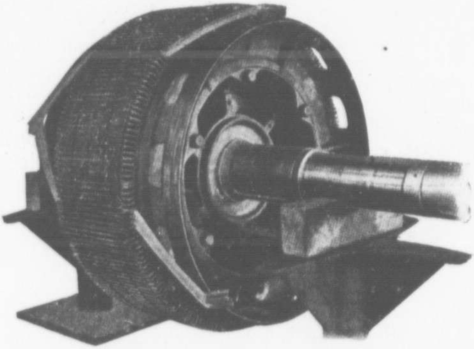


FIG. 7—Rotor of a Wagner 350 horse-power Motor in process of winding.

the air pipe, and the volt is the unit of *electrical intensity,* corresponding to the force (2000 ft. per minute) at which the air is travelling in our illustration. It will be apparent that

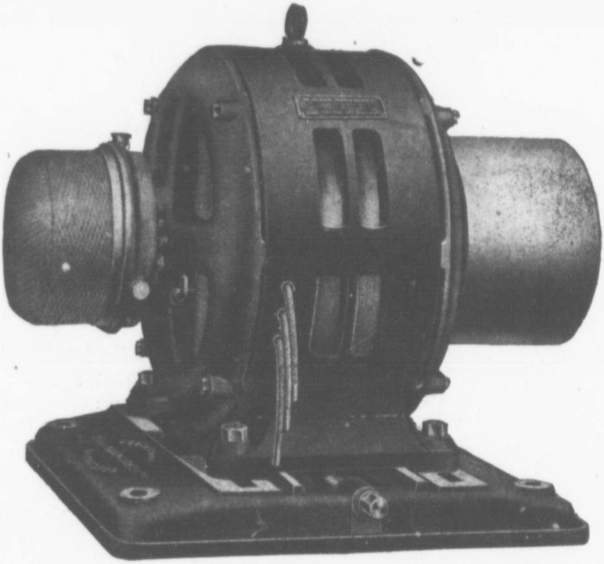


FIG. 8.—Induction Motor—"Slip-ring" type for variable speed.

if we increase the density to 4 atmospheres, keeping the force or rate of travel the same as before, that the amount of resulting force at the delivery end will be just double. If on the other hand we have the same density as at first, but double the force, the result will be the same. Hence, Amperes × Volts = Watts. Thus

$$\left.\begin{array}{l} 746 \text{ volts} \quad \times\ 10 \text{ amps.} = \\ 74.6 \text{ volts} \quad \times\ 100 \text{ amps.} = \\ 74.6 \text{ amperes} \times\ 100 \text{ volts} \ \ = \end{array}\right\} 7460 \text{ watts or 10 h.p.}$$

Now, still keeping to our imaginary illustration, if we know the density and the rate of flow, we know the ultimate power. Likewise, if we know the power and force, we know the density; or given the density and power we know the force. Again, from these given factors, we may know the total *quantity* of air which has passed in a given time. This volume in electricity is expressed by the unit "Coulomb."

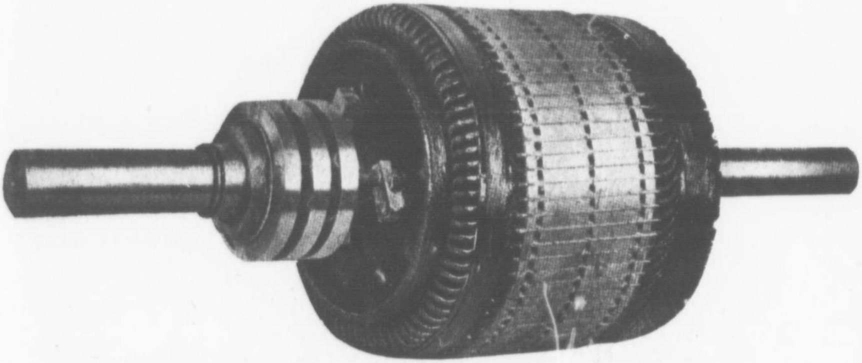


FIG. 9.—Wagner Coil Wound or Slip Ring Rotor for motors of 15 to 75 horse power capacity.

So far we have been imagining that our pipe line is so perfect that it offers no resistance—has no transmission loss whatever. In an actual case we know that this could not be, and it follows that in order to transmit a certain amount we must either increase the velocity or the density to an extent equal to the resistance to be encountered. Supposing we decrease the size of our pipe to an area of 5 square inches, instead of 10 square inches as above. To produce the same results at the discharge end we must either increase the density or the velocity to double that in the previous case, because of the greater resistance encountered. The resistance factor, in electricity, is expressed by the term "Ohm," after the man who first discovered that the relationship we have been noticing applies to electricity as to other forms of energy, and laid down the law know as "Ohm's law."

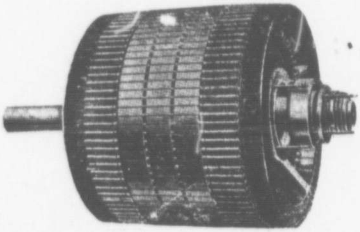


FIG. 10—Standard squirrel cage rotor (patent).

$$\text{Amperes} = \frac{\text{Voltage}}{\text{Resistance.}}$$

Now then it will be clear that 1 ampere × 1 volt = 1 watt, and the amount of resistance will be 1 Ohm. In other words, if there is a resistance equal to 1 Ohm in a circuit, and the voltage is 1, the current density will be 1 ampere. Or if a current density of one ampere is required and the resistance is 1 Ohm, we will require 1 volt of electro motive force. This last term, electro motive force, is generally expressed by the letters E.M.F. Voltage, then, is not power, but the rate at which that power is being pushed along. Now that we have been talking about densities, let me ask—did you ever wonder why a fuse should burst? Let us see how this happens. Come back once more to our air pipe. If you force too great a density upon it, you know what happens. The wall of the pipe is made up of particles of iron which strongly adhere to each other. When the pressure from its centre is greater than the strength of the cohesion of these particles of iron, the pipe bursts.

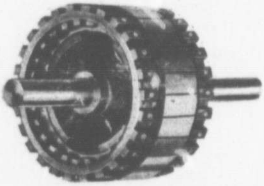


FIG. 11.—Squirrel cage rotor (Packard).

That is exactly what happens when you force too great a density into an electrical conductor. But a copper wire, for instance is not a pipe. How can it burst? Well, take 10 bushels of rough gravel and 1 bushel of fine sand. How many bushels do we get when these are well mixed? Eleven bushels ? No, ten bushels. Because the sand has simply filled the interstices between the gravel. But add more sand—and more, and presently you will have forced the pieces of gravel apart and

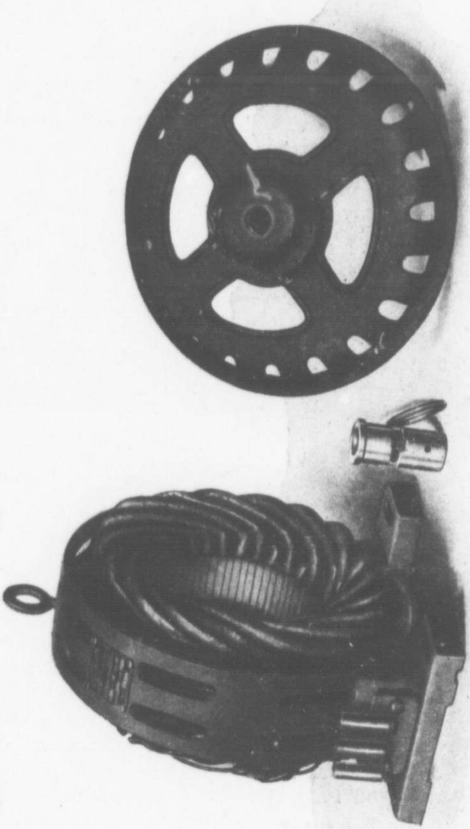


FIG. 12.—Stator and End Frame.

have them separated from each other Now take a copper rod as being made up of small globular particles. There will be interstices in between these particles. Theoretically we will say that the electricity fills these spaces. But increase the electrical density, and the atomic particles of copper (or other material, as the case may be) will become disintegrated—in other words—the wire "burns out" or the fuse "blows." Why then does a fuse "blow" when, for instance, a motor becomes overloaded? Because, whilst the E.M.F. (voltage) remains the same, the resistance is increased and the current density must be increased to overcome this. The fuse is simply a point which is made the weakest point in the circuit and the increased density brings about at this point the result shown above.

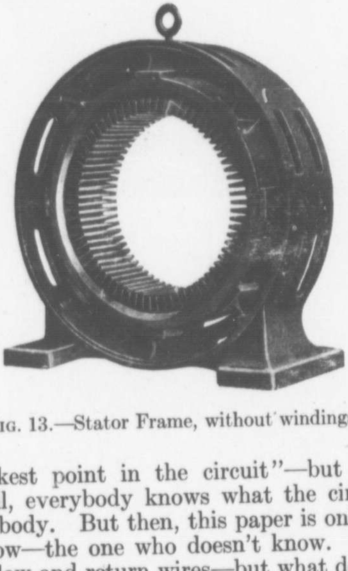


FIG. 13.—Stator Frame, without windings.

"The weakest point in the circuit"—but what is "the circuit." Well, everybody knows what the circuit is. That is, most everybody. But then, this paper is only intended for the other fellow—the one who doesn't know. One man says it means the flow and return wires—but what does that mean?

Now supposing you have two water tanks arranged as in the rough sketch which we will put on our blackboard (Fig. 1).

Tank A is filled with water, whilst B remains empty. These are connected by pipe c, c. There is a turbine midway, through which the water must flow. Naturally the water, when valve D is opened, will flow from A to B until B is filled to the level of the water then remaining in A. In passing through its power will be utilized in turning the shaft of the turbine, E.

This is almost analogous to the electrical circuit. One "pole" of dynamo, or battery, becomes "Positive"—viz., its electrical condition is above the normal,—whilst the other "pole" is "negative," or below normal. Now, the tendency obviously is for the "positive" and "negative" to come to a normal state, and if a wire or any conductor be connected between them, the electricity from the positive will flow to the negative pole until these are equalized. Now, if the pipe connecting our tanks A and B were large enough to allow the water to pass through immediately, it is obvious that the tanks would immediately equalise; and the time taken to equalise will depend upon the amount of resistance offered. So in the electric circuit. Connect a metallic rod right across the terminals of your generator, and since there is no resistance, the electricity flows at once from positive to negative. Of course the density of current will be proportionately great. This is what is known as a short circuit, and explains why, when a "short" happens, a fuse "blows."

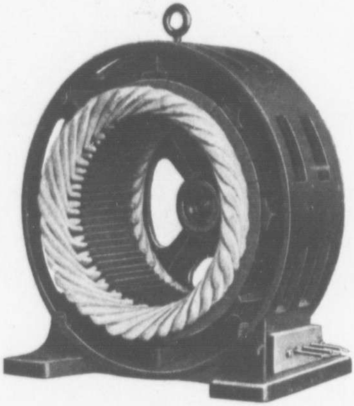


FIG. 14.—Stator complete.

Now, coming back to the tanks: we have a pipe through which the water comes *from* tank A *to the turbine,* and one through which the water goes *to* tank B *from* the turbine. These, in the electrical circuit, are the "positive" and "negative" wires. Place the two tanks side by side, and let the pipe be as long as you like, the result will be the same, except that you will, by lengthening the pipe, have added more resistance and the flow of water will be proportionately slower. This will, by analogy, explain various terms used in reference to the electrical circuit. For instance, the flow of water is less intense with the long pipe, because of the pipe resistance. So in electricity we get drops of voltage on a long line through the line resistance, and this loss is mitigated by using larger wire. Again, the speed of the turbine will depend upon the intensity of the "head" of water and the density of pressure. So in our electrical circuit we have the working force as the product of the volts and amperes.

But notice again: in operating the turbine, how much of the water do you consume—or use up? None at all. You have only made use of the force or energy which was there. So with your electricity. You don't consume "so many kilowatts" of electricity. As it has already been pointed out, and as our present analogy shows, your motor uses the energy, but does *not* consume electricity.

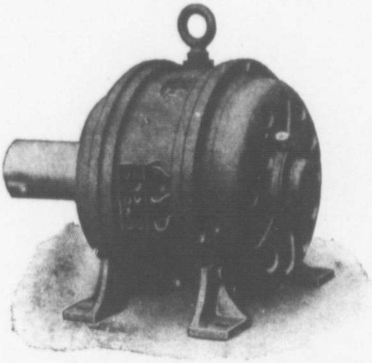


FIG. 15.—Five horse power, 25 cycle "Brook" squirrel cage motor.

This leads us to one of the reasons why alternating current is so largely used. It is impossible to maintain an even voltage on a direct current system when the distribution is spread over a large area Loss of voltage on the line means loss to the power supply concern, but more loss to the customer. In the direct current motor, loss of voltage means loss of speed, lower output, lower efficiency, and higher electricity bills. Nor is this a trifling loss either. It is not unusual, on any but the very most modern direct current systems, to find very considerable line loss, entailing a loss to the customer of sometimes as much as 25 per cent. of the power cost. For this reason partly, direct current systems are rapidly being discarded.

It is well known that high voltages are used in transmitting electricity for distribution. This would not be feasible with direct current because the only way in which you could lower the voltage would be by inserting a resistance such as would use up the "not wanted" energy. For instance we are transmitting direct current energy at 200 volts. We have some apparatus requiring 10 amperes at 50 volts Can we get it? Yes, by putting into the circuit some form of resistance which will take 10 amperes at 150 volts. Now see the result: from our generator we have sent out 200 volts × 10 amperes =2000 watts, although we are only making use of 10 amperes at 50 volts = 500 watts, so that 75 per cent. is wasted. But with alternating current we are able to get what is called "magnetic induction" and this is the fact upon which the whole system of alternating current transmission depends.

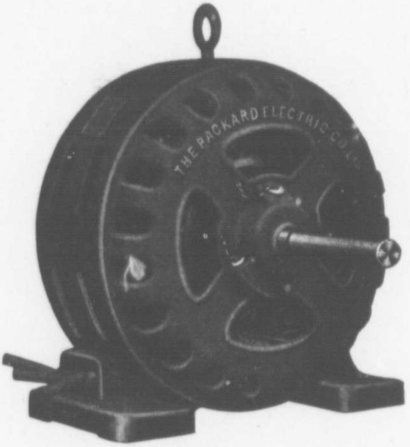


FIG. 16.—Squirrel cage motor (Packard) 25 cycle 3 phase, 15 horse power.

Suppose we have a short bar of soft iron. (Actually the core used is made up of thin plates.) Around one end of this we will wind a large number of turns of fine insulated wire and on the other end a smaller number of turns of thicker wire. It will be found that if we pass a given amount of alternating electrical energy through the first coil, we will have a corresponding amount of energy available from the second coil, the energy in this coil being the result of magnetic induction set up by the first or "primary" coil. Thus, with a properly designed transformer, we could pass into the "primary" coil 1 ampere at 2000 volts, =2000 watts and take from the "secondary" coil 10 amperes at 200 volts or 20 amperes at

100 volts = 2000 watts, or any other proportion that we wished without any loss save a small loss in the transformer itself.

Now as we have already seen, a line will duly carry a certain number of amperes without loss in voltage. Suppose then we have to distribute energy over say 5 miles, and our line has a voltage drop of 15 volts. Suppose we attempt to carry 100 amperes at 100 volts = 10,000 watts. The result at the other end will be 100 amperes at 85 volts = 8500 watts,—a loss of 15 per cent But suppose we transmit 1 ampere at 10,000 volts, and then step down through a transformer where it is wanted, the result delivered will be 1 ampere at 9985 volts = 9985 watts. So that, not only does the use of alternating current permit good voltage regulation but it also ensures economy.

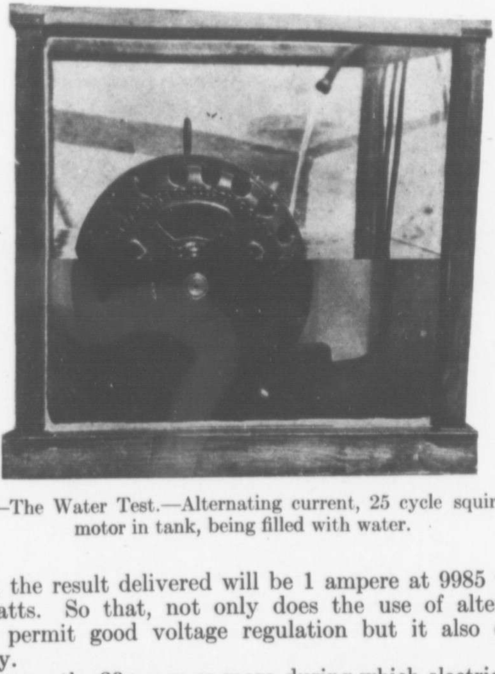


FIG. 17.—The Water Test.—Alternating current, 25 cycle squirrel cage motor in tank, being filled with water.

Of course the 30 years or more during which electric power has been developing has produced the alternating current induction motor, which is now brought to such a pitch of perfection that there is no industrial drive for which it may not be employed satisfactorily. But before talking about alternating current machinery terms, let me attempt to answer the question so frequently asked—What is meant by "alternating current?"

In a dynamo the armature revolves in a magnetic field, each armature coil passing, in rotation, first the north and then the south pole. The result would be a current constantly varying in direction, but for the presence of the commutator. To the segments of this the armature coils are connected, so that the coil when passing the north pole of the field, is connected to the brush on that side, but as the commutator revolves with the coil, it will connect with the opposite brush when the coil is passing the opposite field pole. Our blackboard sketch, (Fig. 2), will probably make this clear. In the alternator, no such rectifying agency exists, the coils of the armature, or "rotor," being connected with the exterior circuit by means of "collecting rings." The general arrangement is somewhat as shown in Fig. 3.

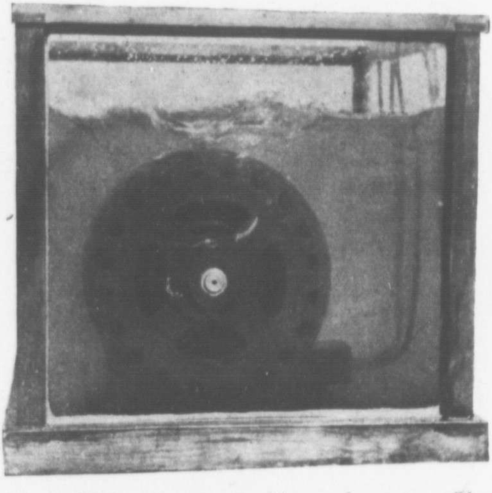


FIG. 18.—Tank filled, and motor working under water without injury. (Reproduced from photo; not re-touched).

The stationary magnet coils are excited with a direct current from a dynamo. When the rotor is in motion an induced current will be set up in the secondary coils attached to rotor. But as each secondary coil passes through alternately a "north" and "south" magnetic field, the current in each coil will vary in direction. Commencing from zero it will rise to positive as the coil comes directly opposite to the first primary coil. Then as the coils pass, dropping to zero again, and when the next coil is reached, going to full "negative." This would give us a "single phase" system. It will readily be seen that a complete "cycle" is made for each pair of coils—zero to positive, positive to zero, zero to negative, and negative to zero. The number of "cycles" per second will of course depend upon the number of such coils and the speed of the generator.

Observe, however, that there are points in each "cycle" when the coils in the rotor are not opposite to any primary coils. Now, suppose we insert another set of coils, separately connected, in the spaces between the secondary coils shown in Fig. 3. Then we will have a second current set up in these coils as they come into position. This would constitute what is known as a two phase system. By proceeding further along the same line we may get a three phase or even a five phase system.

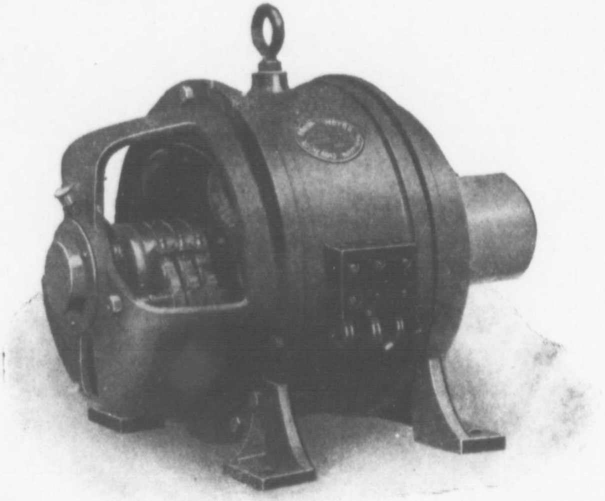
But the alternating current system was not primarily thought out for power purposes. It was in fact, for a long time supposed by many that alternating current could not possibly be used as a power agent, its whole field for a few years being confined to incandescent lighting. As we have already seen, by using alternating current for lighting the voltage can be maintained, and the effect can be seen at once when we notice the lighting in any place where direct current supply is obtained from an outside source. The lamps for a great proportion of the line give little better than a dull red glow.

In early days the tendency was all in the direction of high frequencies, 100 cycles and even higher being common. Now, however, the thing is better understood, the swing is all the other way. Twenty-five cycles per second has now become pretty nearly standard, and one of the reasons for this is the effect of frequency upon the lamp filament.

Fig. 5 (which is taken from Foster's handbook) shows the effect upon a Tantallum lamp filament of alternating current at various frequencies. The 60 cycle lamp gave out first, at 150 hours use, the 130 cycle lamp next, at 300 hours, whilst the 25 cycle lamp continued for 467 hours. The illustration gives us a microscopic view of the filament in either case.

But to come back to the question of motors. The whole story of the rapid development of alternating current machinery is interesting and wonderful, but not within the scope of this paper. Suffice it to say that the single phase motor came into being first, the polyphase motor being a later development. The difference between them may, broadly speaking, be compared to the difference which was made when, instead of just one crank, engines were made with two or three. But in every city the area over which three phase service is given is limited, whilst single phase has a much wider distribution, consequently there is still considerable scope for the single phase motor, and with an increasing demand so much attention has been paid to single phase by manufacturers that this type of motor has now been brought to a high degree of perfection, especially in the smaller sizes. In the United States, the single phase is being widely adopted in railroad work, 25 cycle being the frequency used exclusively, with motors up to 250 horse power. The Westinghouse Co. have the credit of being early advocates of this system; the first railroad to employ it on a large scale was the Indianapolis and Cincinnati Traction Co. which began operation of its track in December, 1904.

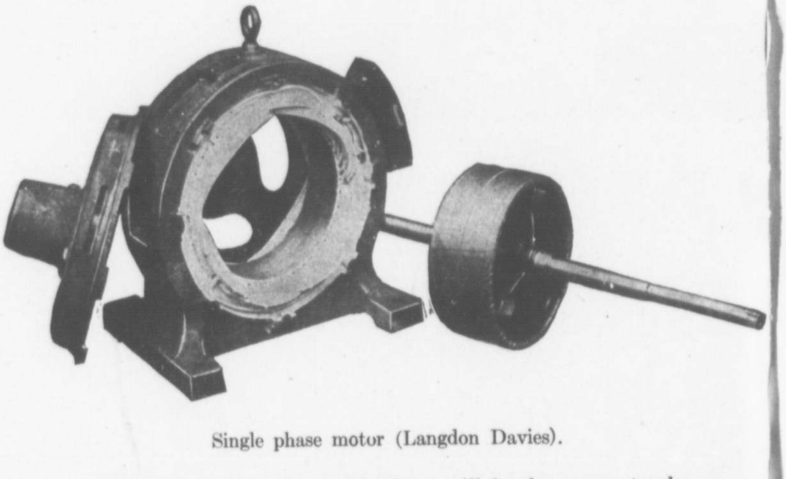
Whether for single or three phase, the principle of construction is much the same. A current is passed through the field or "stator" coils and an induced current is set up in the "rotor," in consequence of which there is a reciprocal "pull." There is a difference in the windings corresponding with the difference between single phase and polyphase in the generator as already explained.



Seventy-five horse power, 25 cycle, 3 phase "Brook" motor for variable speed, showing slip-rings on left.

The polyphase motor may be said to combine all the advantages of the single phase motor with those of the direct current motor, without the disadvantages of the latter. It will start up against full load, will stand considerable overload, and will maintain a constant speed, although it can be built for variable speed and will in this case give a wide range of speed control. This is obtained by the use of a wound rotor with slip rings, as illustrated in Figs. 7, 8, 9. For most ordinary cases, however, the rotor is of the "squirrel cage" type, shown in Figs. 15, 16. With this we have considerable simplicity in construction, and freedom from repairs; there are no moving parts connected with the outside circuit. There is consequently an entire absence of the troubles with armatures, commutators and brushes with which users of direct current motors are all too familiar.

A motor of this type, if of first class manufacture, will show a full load efficiency of anywhere round 85 per cent., often running as high as 90 per cent. Contrast this with the fact that many of the direct current motors in Toronto have efficiencies of only 50 per cent. or even less By the term efficiency is meant of course *the ratio between the electrical energy used and the actual output in horse power hours.*



Single phase motor (Langdon Davies).

Some illustrations herewith given will further serve to show some details of construction. Figs. 10, 11, 12, 13, 14, show parts of squirrel cage motor, the principle in each case being the same. Note that instead of the windings on a direct current armature, solid copper bars are used, and these all short-circuited by rivetting to a ring at the end, or in some similar manner. But Figs. 17, 18, will doubtless be interesting as indicating one of the many advances shown by the alternating current motor. That a motor could be made to work under water without any special protecting arrangements will occasion some surprise, but this can be done with any standard make of induction motor.

It is reasonable to suppose that we are all more or less familiar with some things electrical. Just what, and what not, it is hard to guess. This paper, I repeat, is not for the man who knows, but for the other fellow. I have rambled over a few odds and ends, and probably omitted most of the things I was expected to take up. But this is a social evening anyway, and it is not my purpose to go on indefinitely. So, whilst apologising for having burdened you so far, I will conclude with the words of the storekeeper "If you don't see what you want, ask for it."

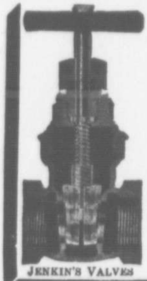
In closing I must add a word of acknowledgement. I am indebted to the Packard Electric Co. and others for their courteous assistance in the matter of illustrations.

EFFICIENCIES OF TWENTY-FIVE CYCLE, THREE PHASE INDUCTION MOTORS.

The subjoined list gives the efficiences, which one well-known firm guarantees, at various load conditions.

EFFICIENCY AT

H.P.	¼ LOAD	½ LOAD	¾ LOAD	FULL LOAD
10	73 per cent.	83 per cent.	85 per cent.	86 per cent.
15	72 "	83 "	83.5 "	84 "
20	75 "	84 "	86 "	88 "
25	77 "	84 "	86 "	88.5 "
32	80 "	86.5 "	87.5 "	89 "
42	83 "	86 "	89 "	89 "
52	83 "	89.5 "	90 "	90 "
75	85 "	90 "	91 "	91.5 "
100	87 "	92 "	92.5 "	92.5 "
120	87 "	92 "	92.5 "	92.5 "
150	88 "	92.5 "	93 "	93 "



JENKIN'S VALVES