velocity and the amount of their attraction by a magnet of known strength according to the formula $\left(\frac{M}{E}\right) v = Hr$, where H is the magnet strength, r the deflection of the stream, and v the velocity of the particles. These three factors being known, $\frac{M}{E}$ the electrochemical equivalent was found. But it was another case where the figures didn't seem in accord with the facts, and when J. J. Thomson recently examined the whole matter anew in the light of new experiments he found the mistake.* It was in assuming that the velocity of the particles was that of atoms in a gas at the given temperature, which, of course, it should be if they were atoms. That velocity is about one mile per second. He found, on the contrary, that the actual velocity of the particles was from ten thousand miles per second up to eighteen thousand.

Now bodies moving with such tremendous velocities, even though very small—as small at atoms—would exert considerable energy when suddenly stopped, and we all remember the mechanical effects which are seen in Crookes tubes, the propelling of a windmill, the heating of a piece of platinum, etc. But when Prof. Thomson actually measured the energy by transforming it into heat, and compared it with the amount of electricity carried along, he found that they did not compare as they should on the theory that they were ordinary atoms with their electric charges. There was too little energy for the amount of matter, or too much electricity.

He found, in brief, that the particles carrying the electricity must be about one thousand times lighter than the atoms of hydrogen, and presumably at least so much smaller.

Here, then, was experimental evidence of the existence of particles many times smaller than atoms. But what are these particles? Is the atom smashed at last—the indivisible divided? It would seem so.

But more suggestive experiments followed. Taking advantage of certain experiments of the Germans, Hertz, Righi, and Elster, showing that violet light would cause the discharge of negative electricity from a charged plate, and that a magnet would deflect the rate of discharge, acting upon the electricity much as it does on the cathode rays, Thompson devised an experiment which deduced the same electrochemical equivalent that the cathode rays gave. The negative current here seemed to consist of particles of the same magnitude as those forming the cathode rays. Could it be that the cathode rays were actually nothing but pure electricity, or that electricity consisted of particles, was an actual substance and not a mere impulse in the ether? It certainly seemed so.

He got a further confirmation of this idea by actually making the electric particles show themselves, or so nearly do it that they could be counted. This was done by making them act as nuclei for mist particles.

It has been proved that water never forms into actual raindrops without particles to form around. Every drop of rain has at its center a particle of some kind. Thomson succeeded in making particles of electricity act as such nuclei for water, and the resulting mist particles were counted. The results agreed with the previous experiments. These experiments leave no escape from the conclusion that atoms can be broken up into much smaller fragments. They do not prove that these fragments are simply particles of electricity. In all the experiments there may have been present with the electricity a fragment of matter.

When we consider for a moment how electricity is generated, it seems, at first sight at least, that it could not give any of the mass effects of material substance. But let us examine more closely. When two bodies are brought together and then separated, what is called an electric field is formed between them, that is, the medium between them is under a strain, tending to bring the bodies together. There is really no electricity or electric current between them, only a strain or stress as though they were connected together by elastic bands. The electricity is all at the ends on the bodies. If the bodies move the strain moves with them, not the ether; that remains rigid. They pass through it or it through them without any friction or resistance at all. But the ether left behind does not at once come back to its original condition, neither does that ahead of the motion take up the strain instantly. It takes time to adjust itself and in the adjustment magnetism develops. This magnetism acts upon the ether in its neighborhood, producing another strain, which has two effects, one to send pulsations through the ether with the speed of light (these are the ether waves by which wireless telegraphy acts), and the other to cause a current of electricity to pass through a conductor properly placed, but in the opposite direction to the original current. We have, then, in such moving bodies first the original ether strain or electric field surrounded by its magnetic field, and this in turn accompanied by another ether strain which will cause a current opposite to the first. This is the induced current, so-called, which does the work on our electric railroads, etc. These currents oppose each other or perhaps rather the magnetism between them tends to stop them, so the more the induced current is carried off the more magnetism there is to pull back, and the harder it is to keep up the motion of the generating bodies, or rather body, for in practice the revolving armature is the moving body. Thus we see in a central station how much more power it takes to turn the armatures of the dynamo when more current is drawn off by the wires. We see nothing at all to impede its motion, but it behaves exactly as a saw does when being forced through a log. The inertia being overcome by the revolving armature is electric and not material, but the behavior of the two is very similar. Electricity, then, may cause inertia when in rapid motion. But the particles moving in the Crookes tube are in rapid motion, and must likewise be accompanied by magnetic fields and induced currents, and so their inertia may be due to such a combination, and the necessity of having matter with them to account for their heating effects is avoided.

But if it is not necessary to suppose anything different in this case, why must it be in any case? Why may not the material atom itself be simply a collection of these electric particles, and so all matter be resolved into electricity? This, indeed, is what is now being claimed. According to this view there is nothing really in the physical universe but electrons and ether, and perhaps, as in Lord Kelvin's idea, the electrons are made of ether.

The elementary atoms are groups of these electrons, which are of two kinds, positive and negative. Different numbers make different atoms. Thus the hydrogen atom may consist of about 700 while the mercury atom consists of perhaps 100,000. These electrons, except for being positive and negative, are exactly alike; the different numbers grouped and different motions make up the different kinds of matter. One would suppose that, where so many are crowded together in such a small space as that of an atom one three-thousand-millionth of an inch in diameter, they could not be very free to move, but quite exact calculations show that the space not occupied by them is at least ten thousand million times as great as that occupied, so they must be as free to move as the planets in their orbits and collisions between them about as rare. It is supposed also that around each group making an atom are certain loose ones, so to speak, electrons less firmly held, which may be pulled off by neighboring atoms just as comets may be drawn into our system when they get near enough. These cause electric currents and chemical attraction, etc.

It would seem that an atom composed of such a moving collection could not be very stable, that it might disintegrate, and these electrons all fly away to other atoms or remain free in the air. Curiously enough, that seems to be just what we are finding out does happen, especially in the case of the negative electrons. The positive seem to be less liable to do this. Thus, as we have seen, the influence of an extra charge of negative electricity sends free negative electrons streaming through the Crookes tube. A ray of violet light separates them when collected on a surface. It is believed that when a gas conducts electricity it always does it partly by free electrons coming from break-up of atoms. In all these cases there is an impulse or shock which frees them, but in many substances they seem to come off spontaneously. Several new substances, radium, polonium, etc., give of themselves constant discharges of electrons, and almost every day some new substance is discovered which does this. Thorium and its compounds, uranium, hydrogen dioxid, and many others, give off constantly these radiations believed to be due to breaking up of atoms and sending out of their electrons. It would seem as though the air must be full of these floating electrons.

One of the necessary results of this theory seems to be that we must give up the old idea of the indestructibility of matter. Some of it must be constantly undergoing destruction, and the flying fragments are bombarding us on every side. And these flying fragments hit hard, too, if there are enough of them. A minute fragment of radium inclosed in a tube and put in the pocket would soon raise a blister on the skin underneath the clothing, and it has been estimated that it would be as much as a man's life is worth to go into a room where two pounds of radium was kept in a case. Fortunately there is no prospect of such a quantity ever being obtained. But why have our delicate balances never yet been able to detect this destruction of matter? Because they are not delicate enough. We cannot weigh the perfume of a rose and yet we know it is material. We cannot weigh as small bodies as we can see with our microscopes and we know how much smaller atoms are, and how much smaller than atoms electrons are.

It is estimated that the rain of electrons in a Crookes tube would need to be kept up one hundred years before the material carried could be detected as gain or loss of weight by our most delicate balances. But this destruction of matter is not real destruction, in one sense at least. It is a breaking up of material atoms, but these fragments still exist and may group themselves or be grouped into material atoms again.

The most puzzling thing about the whole subject is, whence comes the energy which supplies the motive power by which a substance like radium keeps up its constant discharge of electrons? Must we conclude that our theory, long held, of the conservation of energy is untenable also? It is not at all necessary to do that. But we must enlarge our ideas of the possible sources of force. For a great many years all the forms of energy we were acquainted with could be resolved into the well-known forces, heat, light, electricity, magnetism, gravitation, chemism, and it is hard for us to think of the possibility of other sources. But it has always been held that there possibly were atomic and molecular motions not manifested in such ways, and now, perhaps, we are seeing evidence of these. There certainly is plenty of unused energy in nature. Consider for a moment the energy in the atoms of what seems to be perfectly quiet air. Instead of being matter at rest, it is made up of particles moving with enormous velocities. A cubic yard of quiet air possesses an energy equal to one hundred and forty thousand foot pounds. We get no evidence of this and cannot utilize it because it is used up in collisions among the atoms themselves. The swiftly moving atoms strike the slower moving, and energy is changed from one to the other, but the temperature of the whole remains the same. If there were any way by which the slow moving could be rapidly separated from the mass, the residue would grow rapidly hotter and energy would seem to have been created, but really it would not have been. It is the energy already existing, made manifest. Now it is conceivable that radiating substances like the new element, radium, are sensitive to the impact of atoms moving at a certain rate, and not to others. Thus the ceaseless stream of energy they send out is not self-manufactured from nothing, but comes from changes in other matter which hitherto we have been unable to utilize.

If this be true, and some lucky discoverer finds out why and how it does it, and succeeds in improving upon this, constructing a substance which will have this power many thousand fold, a revolution in motive power will have been made which almost swamps the imagination.

Instead of looking to steam and water power for our industrial service, we should simply expose our radiating material, and it alone would run our factories or heat or light our rooms, and we at last be free from the pressing fuel problem.

But, as I said at the beginning, theorizing must be checked or it will run away with us, and I fear these last ideas may indicate that I am perilously near that condition now. Remember that this electron theory is still but a theory, and in its infancy at that. But I believe the facts on which it is based will be enlarged rapidly, and that very many practical results will be worked out from and by them to the great benefit of man in his struggle with material things.

* See recent address on "Electrons" by Sir Oliver Lodge in SCIENTIFIC AMERICAN SUPPLEMENT.

ON POLONIUM AND THE INDUCING CHARACTER OF RADIUM.

By F. GIESEL.

IT has been found by Marckwald (Berichte, 1902, xxxv., 2285, 4239) that metallic bismuth which is immersed for some time in a hydrochloric acid solution of Curie's bismuth polonium acquires to a remarkable extent the property of emitting α-rays. Marckwald considers that the precipitate formed on the bismuth consists, at any rate in part, of metallic polonium, and regards the electrolytic separation as the proof of the existence of an (electro-negative) element differing from bismuth and allied to tellurium.

I (Berichte, 1902, xxxv., 3608) was successful in confirming Marckwald's observation with my purified polonium preparations, only no trace of a precipitate or a coloration was to be seen on the bismuth. As the non-appearance of a precipitate seemed to argue against Marckwald's theory, and in any case the prospect of obtaining sufficient quantity of the element in question was very remote, I tried to approach the question of the nature of polonium in a different manner.

In attacking this problem, I was guided by the opinion which I had previously expressed, that polonium may be bismuth acted upon inductively by radium, a view which was forced upon me by experience in direct experiments repeatedly performed when preparing preparations of polonium (Berichte, 1902, xxxv., 3610). As in my earlier experiments less attention had been paid to α-radiation, and I had recently found (Berichte, 1903, xxxvi., 729) that this was developed both in metallic bismuth and also in platinum and palladium by the action of a solution of bismuth polonium chloride, it was important to investigate how a radium solution would behave. It may be safely asserted that the clean surface of the metals guaranteed the possibility of perfectly removing every trace of the soluble primarily active reagent which cannot be vouched for in the case of precipitates even with the most careful washing. This appears all the more important when it is remembered that even one-half a millionth part of radium salt, present as an impurity, is sufficient to cause appreciable phosphorescence of the barium platinum cyanide screen.

In fact, it is now easily possible to impart to bismuth or the platinum metals, by momentary contact with radium, properties which exactly resemble those produced by polonium.

If a freshly cut piece of bismuth is placed in a solution of 0.01 gramme radium bromide in 1 cubic centimeter water, after remaining there for one to two days, the bismuth shows strong α-radiation and no β-radiation.

Note.—The non-appearance of β-radiation, after keeping for two weeks, may perhaps be employed as a control experiment for demonstrating the absence of radium. For testing for α-rays the zinc sulphide screen was used, and for β-rays the barium platinum cyanide screen. All α-radiation produces on the zinc sulphide screen the scintillation described by Crookes, and observed by Elster and Geitel, while the β-radiation appears to produce only uniform illumination. The effect of a current of air on the scintillation can only be observed in the emanation of my emanation substance (Berichte, 1903, xxxvi., 342).

The greatest possible care was taken to remove every trace of radium salt from the bismuth.

Platinum-wire and palladium-foil, before being introduced into the radium solution, were rubbed with emery and sea-sand, washed with hydrochloric acid and distilled water, and ignited. After treating with radium solution, like the bismuth, they were carefully washed with hydrochloric acid and distilled water to free them from the radium salt.

Bismuth is decidedly superior to the platinum metals in acquired activity, and seems to be best suited for accumulating the positive electrons of radium. It is noteworthy that the part of the platinum wire which was beyond the end immersed in the radium solution in the test-tube, and thus was only in contact with the air, also showed decided activity (α-radiation). The line of separation of solution and air was marked on the wire by a short zone of greatly diminished activity. The α-radiation thus artificially communicated by the radium to the bismuth, palladium, and platinum shows no decrease, as far as has been observed. As it has hitherto always been found that the activity caused by induction diminishes with the time, comparatively speaking quickly, it is of great importance to investigate the limitations of this law by the manner and kind of induction, for which a longer time of observation is necessary.

The small quantities of bismuth and palladium passing into the hydrochloric acid solution in the above experiments were precipitated with sulphureted hydrogen. The precipitates (especially the palladium sulphide), in spite of repeated washing, emit β-rays strongly. From what has already been said it could not be deduced whether this radiation is due to the adherence of radium; it can only be shown how it behaves with regard to the constancy of the activity.

I was able also to confirm the observation of the Curies, concerning the development of heat by radium, which can be proved in a very simple way.

If a thermometer is lowered into a glass flask containing 0.7 gramme radium bromide, in a short time it rises 5 deg. above the temperature of the surroundings, and remains at this temperature as long as it is kept in the flask. When held over a capsule closed with a sheet of mica and containing 0.3 gramme radium bromide, the thermometer showed an increase of temperature of almost 2 deg., if it was protected from currents of air.—Berichte d. Deutsch. Chem. Gesell.

THE TRANSMISSION OF A 23,000-VOLT DIRECT CURRENT OVER A DISTANCE OF THIRTY-FIVE MILES.*

By Emile Guarini.

The recent installation of a hydro-electric plant at St. Maurice, near Lausanne, Switzerland, represents the only one of its kind in the world. It is unique,

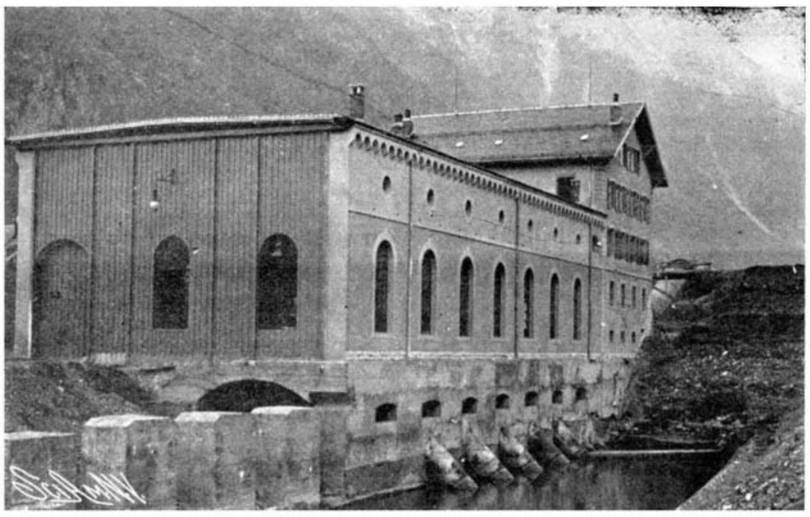

Fig. 1.—THE POWER-HOUSE AT ST. MAURICE.

without a doubt, being the only plant thus far erected from which a direct current is sent out at a tension of 23,000 volts and transmitted over a line 56 kilometers (34.77 miles) long. This power plant demands the attention of expert electricians because the Compagnie de l'Industrie Electrique of Geneva have, by its erection, violently set themselves against the tradition which demands the use of the alternating current, with its accompanying up-and-down transformers, for long-distance transmission, and have worked out the problem for the direct current by means of a series system invented by Mr. Thury, the engineer-in-chief of the company. Already, as early as the year 1898, with the intention of providing itself with power and light, wherewith to effect a considerable development of its industries, the commonwealth of Lausanne acquired the power to take from the Rhone River at St. Maurice a force equal to 15,000 horse power by utilizing the rapids of the Black Forest.

Having obtained the concession, it next became a question how to transmit this immense power safely and economically from St. Maurice to Lausanne, about 56 kilometers distant. Accordingly a call for competitive offers for the construction of such a plant was issued, and the expert electricians who were intrusted with the examination of the bids, and thereby with solving the knotty problem, after carefully weighing the different projects presented for the transmission of the required energy, some by means of a direct current and others by three-phase currents, did not hesitate to decide in favor of the system comprising a direct current in series. Their choice was determined first of all by the safety of its utilization, by a consideration for the more facile regulation of the light, and still more by the obvious economy of its construction. Indeed the capital required for the establishment of the first plant under the direct current in series-system proposed by the Compagnie de l'Industrie Electrique et Mécanique, was only 7,365,000 francs as compared with 8,105,000 francs for the installation of a three-phase-current plant of the same capacity, being a difference in favor of the direct current installation of 740,000 francs.

Accordingly the Compagnie de l'Industrie Electrique et Mécanique was commissioned to erect the first installment of the plant, constituting about one-third of the available power of the completed plant, say about 5,000 horse power, under the series system.

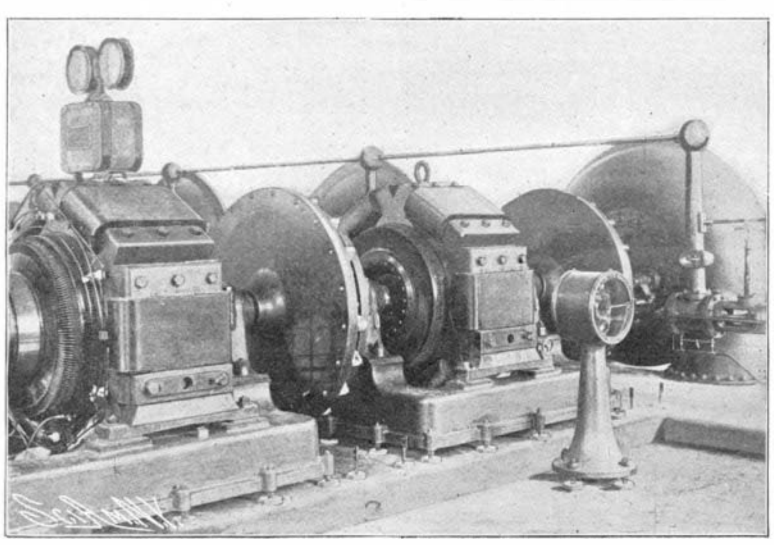

Fig. 2.—1,000-H. P. UNIT CONSISTING OF TWO DYNAMOS, EACH GENERATING A VOLTAGE OF 2,600, CONNECTED IN SERIES.

For the generation and transmission of this amount of power, there are required at the generating station at Saint Maurice, shown in Fig. 1, five 1,000-horsepower units, each consisting of two dynamos direct connected to each other and to a turbine. Under a full load each of these units will deliver 150 amperes at 4,500 volts.

Fig. 2 shows one of these units, each of the two dynamos of which, connected in series, generates a 150-ampere current at a voltage of 2,250. By connecting the five units in series, the total energy of the plant is obtained at a tension of 22,000 volts, the highest voltage for a continuous or direct current in actual existence. The foundations for the building have been erected upon the edge of the runway canal, and extended, with a view to the accommodation of the remaining two groups of units which will complete the 15,000 horse power at first intended. The inauguration of this most remarkable transmission of power, accomplished a few months ago, was clothed with a character of veritable scientific and technical solemnity. The most distinguished representatives of the great electrical and mechanical reviews of the Continent were present at these interesting trials. The tests with a full load were attended with complete success at a tension of 23,000 volts under a constant intensity of 150 amperes. To do this there were provided at the receiving station, 56 kilometers away, a series of twenty large vats with circulating water for the absorption of this immense energy. Besides the direct-current machines for the sending of the electric energy over the long line, this generating station also contains two groups of three-phase dynamos, shown in Fig. 3, which produce the current used in lighting St. Maurice. The reader will no doubt remark that this installation of power appears to be verily a "world turned upside down," so to speak, in which use is made of the direct current for long-distance and an alternating current for short-distance transmission.

Each unified group of the direct-current machines carries a voltmeter and an ammeter mounted upon the frame of the field of one of the dynamos.

The distributing board of each group is reduced to a simple column shown in Fig. 4, inclosing a short-circuit switch, which permits the short-circuiting both of the general wiring system and of any unit of two machines at the same time, as well as the cutting of the dynamos out of the system altogether.

The stepping-in of any individual unit is a very simple matter, for by the gradual opening of the gate to the penstock of the turbine, the machine is slowly started and acquires shortly the necessary speed, being self-excited by short circuit.

When the delivery in the short circuit is equal to 150 amperes, the group is cut into the main circuit by the manipulation of the short-circuit switch, and this is accomplished without any sparking. At first the load of each unit is regulated by hand, but afterward the governor of the turbine is connected with the automatic governor which acts in general upon all the units of the plant. This voltage regulator is of the Thury type and is shown in Fig. 5. It receives its motive power from a small bipolar motor operated by means of an induced current derived from the main line. This motor, which runs at a speed of 1,700 revolutions a minute, requires a current of 50 amperes when running light and 60 amperes when loaded, at a tension of 2.3 and 2.4 volts respectively, which, by the way, is the floating voltage of a small storage battery connected in parallel, that forms a reserve in case there be any interruption in the main line.

In this case the armature of an electro-magnet falls upon the ratchet gear wheel of the regulator, which immediately assumes the position necessary to shut off the turbines; while the small motor continues its work, fed by the current from the storage battery. Of course the ultimate stoppage of a group of units is effected by cutting off the water power from the driving turbine, which is gradually brought to a standstill by the resistance of the now idle water about it, in which it turns, dragged around by the momentum of the dynamo, now acting as a motor; meanwhile the automatic switch short-circuits the dynamo. An ammeter, a voltmeter, and the connections which run to the lightning-arrester box constitute the whole of the main switchboard of the plant. Upon a visit to the receiving station at Lausanne we find the customary procedure in such a station has been reversed. Ordinarily, alternating currents are stepped down and converted into direct currents; but here in the establishment at Lausanne the direct current is converted into an alternating current. Installed in the building here are five direct-current motors coupled in series, of 400 horse power each, which absorb 150 amperes at 2,100 volts. Of these five, four are coupled direct to alternators, whose function it is to distribute the electric energy through two specially provided circuits, one for the electric lighting, and the other for motive power, serving at one and the same time the city of Lausanne and the surrounding districts.

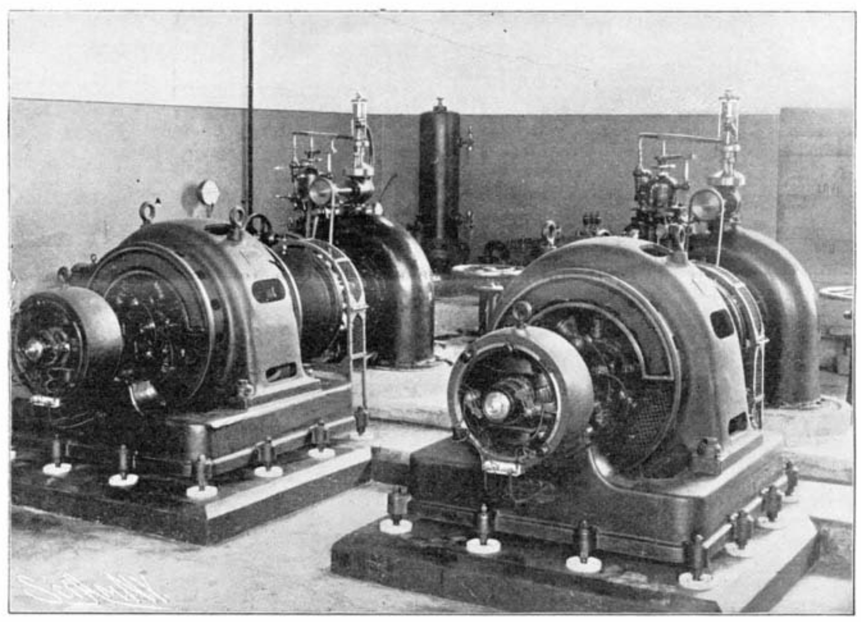

Fig. 3.—A GROUP OF ALTERNATING-CURRENT MACHINES (150 H. P.).

In Fig. 6 we present a view of one of these groups. Two of these alternators may equally well be coupled with Sulzer steam engines, which are intended to be used as a reserve. The fifth motor is coupled to a tractive generator, of the Thury type, which produces 400 horse power at 600 volts.

A second tractive generator of the Thury type and a storage battery with a Thury booster complete the equipment. It is worth remarking that, for its experiments upon the insulation of the line from St. Maurice to Lausanne, the Compagnie de l'Industrie Electrique of Geneva has constructed a dynamo which is capable of a current of one ampere under a tension of 25,000 volts. Enormous progress is here evinced, since up to the present the highest tension obtained for a simple direct current was 10,000 volts and that with difficulty. It is also a fine showing to have doubled by more than half, the admissible tensions, and do it at one stroke, too.

The services which this machine is capable of rendering and has already rendered are very considerable. While testing out the high-tension line from St. Maurice to Lausanne, this machine was of inestimable assistance in discovering leaks caused by the branches of the trees coming in contact with the wire, losses so small that the galvanometer did not register them. Moreover, it has been employed in testing high-tension cables. It affords also an opportunity for many very curious and interesting experiments upon the combination of gases under the influence of the electric arc at high tension, such as, for instance, the combination of azote (nitrogen) and oxygen in the manufacture of nitric acid. In fine, scarcely a day passes but it is employed in many experiments which it would be impossible to make without its valuable aid. We are

* Specially prepared for the Scientific American Supplement.