attempt to drive from certain portions of the soil the worms, snails, and other noxious insects which infest it, by an accidental observation made while at work upon the experimental drying by electricity of an ingot mold built directly in the ground.

After the current had been turned on for a few moments, Mr. Helberger incidentally remarked that, out of the ground adjacent to the mold, worms were coming hurry-skurry, as if pursued by some unseen antagonist, and doing their utmost to flee from the disturbed locality. He also observed that on passing from one clod to the next they were thrown back, rearing up and contracting convulsively.

In his opinion, these actions on the part of the worms could only be attributed to the influence of the electric current. In fact, they ceased when the flow was shut off.

Following up these observations, Mr. Helberger undertook several tests calculated to prove or disprove his hastily conceived theory. Among others, he buried in the ground a bar of brass about half a centimeter thick, and connected it with one pole of an electric conductor carrying a current of 110 volts. Upon turning on the current, the results of this arrangement far exceeded what he had only chanced to observe in connection with the ingot mold, for within a radius of two meters every worm or insect, till then snugly ensconced within the lap of friendly Earth, came to light and hurriedly sought safety in flight to securer positions, which were apparently only attainable beyond the electrified circle. Carrying the idea further, he now increased the electrified circle by planting other brass electrodes in the earth, and, in a shorter time than it takes to tell it, freed the surrounding terrain of all that it contained in the nature of crawling or creeping things. In itself the current is very small or weak, only the tension must be high.

These experiments opened to the thoughtful mind a wide field. If the practical application of the electric fluid to the earth should work such wonders upon uncultivated ground, what might not be the benefit which would accrue to agriculture in general if applied upon a vast or at least a more extended scale? Surely, he thought, a plant, the roots of which are free from attack by worms, snails, beetles, and what not, must thrive and flourish far beyond one which was continually under tribute to these subterranean depredators.

It is now generally admitted without contention that the virtual extermination of these harmful insects from the neighborhood of growing plants, by means of the electric fluid, is a happy circumstance for agriculture; indeed, the experiments undertaken by Mr. Palumbo verified this fact in 1901, not accidentally, as was shown above, but by methodically bringing some worms and ants between two portions of earth connected to an electric generator. If our readers possess sufficient interest to investigate these trials, an account of them will be found in the issue of the Revue de l'Electricité, which appeared at Berne, Switzerland, on the 31st of January, 1903. It cannot be admitted, however, as some scientists and others seem to think, that electricity is baneful to the soil just because it does drive away these worms and insects.

Quite the contrary is shown by the results of the researches and experiments undertaken by Mr. Lemstroem, a professor at the University of Helsingfors, not to mention other investigators, all of which go to prove the beneficial influence of electricity upon vegetation.

This mysterious influence so powerfully exerted is explained in this wise: The passage of the electric fluid causes the electrolysis of the salts contained in the soil, decomposes them, in other words, and recomposes, or forms them into new compounds or salts more easily assimilable by the plants; again, it excites new vigor in the vitality of the plant, and in that way favors the interchange of gases between the leaves on the one hand and the surrounding atmosphere on the other; it, moreover, actuates the respiratory organs, aids the fixation of the carbon, assists the transpiration, the nutrition, and the multiplication of the cellules; in fine, it urges on the ascension of the sap by stimulating osmosis and by causing the life-giving fluid to penetrate into the farthest recesses of the capillary vessels of the tissues of the plant.—Translated from Cosmos.

SOME EXPERIMENTS ON THE ELECTRICAL CONDUCTIVITY OF ATMOSPHERIC AIR.*

By J. C. McLENNAN, Ph.D., Associate Professor of Physics, University of Toronto, and E. F. BURTON, B.A., Fellow in Mathematics, University of Toronto.

I. INTRODUCTION.—In a paper by H. Geitel† reference is made to a gradual increase observed in the conductivity of a mass of atmospheric air after being confined in an air-tight chamber. This effect was found to require from four to five days to reach its maximum value and was observed in localities where no thorium compound or other known radioactive substances existed. In a subsequent investigation Elster and Geitel‡ found that air which had been confined for some time in closed caves or house-cellars possessed an abnormally high conductivity. This phenomenon, together with the observed increase in conductivity mentioned above, they concluded, could not be due to the presence of dust or water vapor. They traced it rather, in both cases, to the existence of some undetermined radioactivity in the confining walls. More recently these physicists* discovered that atmospheric air possessed the property of exciting induced radioactivity in bodies exposed under negative electrification. This phenomenon of induced or excited radioactivity had been previously observed by Rutherford† in bodies exposed to air drawn from the neighborhood of thorium compounds and had been connected by him very directly with an emanation which these salts emit. This emanation he found possessed the property not only of exciting radioactivity in all solid substances in the neighborhood, but also of ionizing any gas with which it was in contact.

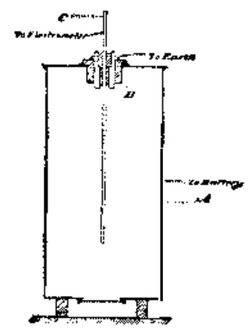


FIG. 1.

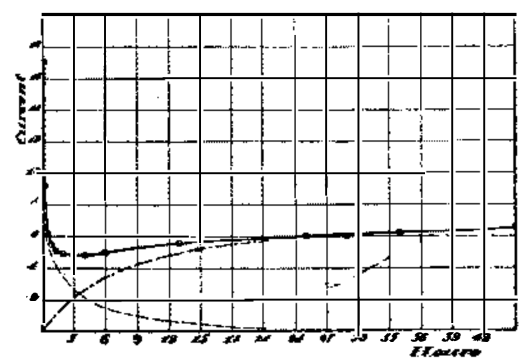


FIG. 2.

Since atmospheric air has been shown by Elster and Geitel,‡ C. T. R. Wilson,§ and others to be continually ionized by some agent, and since it has also been shown to possess the property of exciting radioactivity, one is forced to conclude that there is present in the air an emanation possessing properties similar to that emitted by thorium compounds. Hitherto the source of such an emanation has not been determined, but, as the phenomena of induced radioactivity and spontaneous ionization universally characterize atmospheric air, it seems evident, since thorium compounds are but sparsely distributed in nature, that sources other than these must exist.

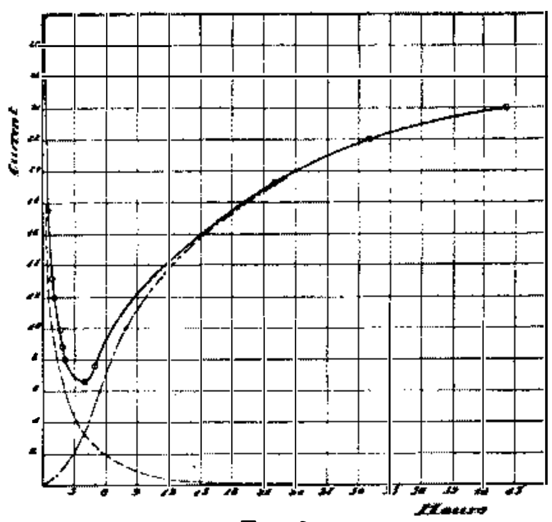


FIG. 3.

Recalling the experiments of Elster and Geitel, it seems probable that the earth's surface, and possibly too, the material used in the construction of their apparatus, are sources of this emanation. As but little evidence existed in favor of this conclusion, the writers recently made a series of observations upon atmospheric air confined in air-tight vessels of different metals. The result of the investigation showed that the conductivity of the inclosed air depended very largely upon the material of which the receiver was made, and the effects observed would seem to indicate that all metals in varying degree are the sources of a marked though feeble radioactive emanation.

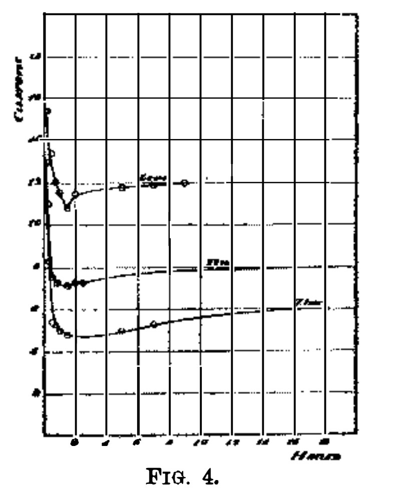


FIG. 4.

II. Apparatus.—In these observations the air whose conductivity was to be measured was confined in a cylinder 125 cms. in length and 25 cms. in diameter, similar to that shown in Fig. 1. In the first experiments it was made of sheet iron coated with zinc, and in the later experiments linings of various metals were inserted in order to examine their effect upon the conductivity of the inclosed air. The bottom and cover were removable, and, when in position, were made air-tight by means of cement. Into a flanged opening in the cover was fitted an ebonite plug about 5 cms. in diameter. A brass tube, *B*, was passed through this, and into it a second ebonite plug was tightly fitted. This second plug carried a brass rod, *C*, which extended almost to the bottom of the cylinder. The brass tube, *B*, which was earthed throughout the measurements, served as a guard ring and prevented any leak from the vessel to the rod, *C*, across the ebonite plugs. The conductivity was measured by placing the cylinder upon an insulated platform, charging it by means of a set of small storage cells to a potential of 165 volts, which sufficed for the saturation current, and observing the rise in potential of the electrode, which was joined to a quadrant electrometer in the usual manner. The sensibility of the electrometer was such as to produce a deflection of 1,000 millimeters on the scale for a potential difference of one volt between the quadrants.

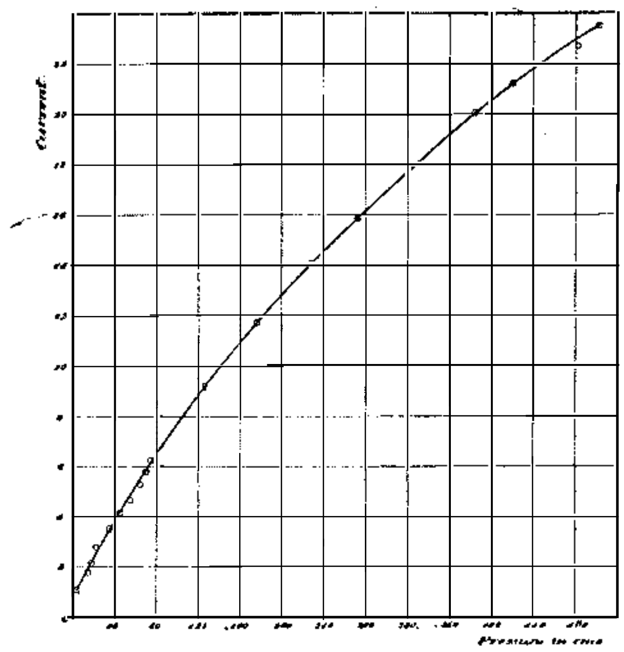


FIG. 5.

III. Conductivity Measurements: Time Effect.—Before inclosing air for examination, the cylinder was placed in an open window in the laboratory, with the ends removed, and the air allowed to blow through it for some time. The top and bottom were then replaced, cemented in position, and the cylinder connected with the electrometer as quickly as possible. Measurements on the conductivity were made at intervals of a few minutes at first, and it was invariably found that a rapid decrease in the ionization took place until a minimum value was reached. The conductivity then slowly increased and approached a limiting value in the course of two or three days.

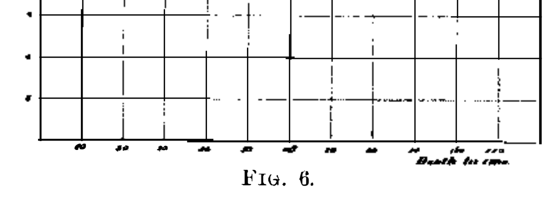


FIG. 6.

TABLE I.—CURRENT: ARBITRARY SCALE.

Time.	Pressure—501.0 cms.	Pressure—74.2 cms.
10 mins.	30.0	17.1
15 "	....	9.3
30 "	17.5	6.2
50 "	13.2	5.5
1 hour	12.0	....
1.25 "	....	5.13
1.5 "	9.9	....
1.75 "	8.9	5.1
2.00 hours	8.0	4.9
4.00 "	6.6	4.8
5.00 "	7.6	....
6.00 "	....	5.0
10.00 "	....	5.8
22.00 "	19.2	....
25.00 "	....	6.0
29.00 "	....	6.0
32.00 "	22.0	....
34.00 "	....	6.3
44.00 "	24.0	....
45.00 "	....	6.5

* Read before the American Physical Society at Washington, December 31, 1902.

† Phys. Zeit., ii, pp. 116-119 (1900).

‡ Phys. Zeit., ii, pp. 560-563 (1901).

* Phys. Zeit., ii, p. 590 (1901).

† Phil. Mag., No. 49, pp. 1 and 161 (1900).

‡ Loc. cit.

§ Proc. Roy. Soc., vol. 69, pp. 277-282 (1901).

In repeated tests carried out in this manner with the zinc cylinder it was found that, while the initial conductivity varied from day to day, there was always observed a rapid decrease to a constant minimum followed by a gradual rise to a constant limiting value. A typical set of values for the conductivity of air confined in the zinc cylinder at atmospheric pressure is given in the third column of Table I, the currents being expressed in arbitrary units, and the times being taken from the closing of the cylinder. The ionization curve for these values (Fig. 2) shows that the minimum current, 4.8, was reached in about four hours after the air was inclosed. After about eighteen hours the curve indicates that the conductivity was tending toward a limiting value, which the reading taken after forty-four hours showed to be about 6.5.

As a variation in the experiments, a series of tests was made with air confined in a receiver at high pressures. The cylinder in this case was of heavy rolled iron, coated with zinc, and was of the same dimensions as that formerly used. The results of observations on the conductivity of air confined at a pressure of about seven atmospheres are given in the second column of Table I, the scale used being the same as before. The curve representing these values is shown in Fig. 3, and exhibits the same characteristics as that for the lower pressure. We have again the rapid decrease to a minimum, followed by a gradual rise tending toward a limiting value. The minimum conductivity in this case was about 6.6, and was reached in about four hours after the required pressure in the cylinder had been obtained. The time occupied in pumping the air was about one hour.

In seeking for an explanation of the curves shown in Figs. 2 and 3, their twofold origin, as indicated by the dotted lines, is at once suggested by the conductivity in the initial stage being due to an agent subject to rapid decay, and that in the second to one whose power shows a gradual increase. The first of these dotted curves is similar to that given by Rutherford* for the conductivity of the air in a chamber which has been cut off from a second containing thorium oxide after the two had been in communication for some time. The second dotted curve is similar to that given by him for the conductivity of the air in a chamber which had been placed in communication with one containing thorium oxide.

It will thus be seen that the first portion of the curves in Figs. 2 and 3 can be explained upon the supposition that a radioactive emanation, probably having its origin in the earth's surface, was introduced into the cylinder with the air, the decay in this emanation being the cause of the decrease in the conductivity, and the second portion upon the supposition that a radioactive emanation is given off by the walls of the containing vessel. On this view, the limiting value to which the conductivity curves tend would represent a condition of equilibrium, where the rate of decay of the emanation is equal to the rate at which it is produced.

As both the low and the high pressure cylinders were made of the same material and were of the same size, one would expect the same amount of the emanation to be present in both when the steady state was reached. With an easily absorbed radiation from this emanation, we should obtain a limiting conductivity independent of the pressure. But, since a very great difference was found in the limiting conductivities at the two pressures, it would appear that the radiation possesses considerable power of penetration and is not easily absorbed.

The difference in the initial conductivities given in the second and third columns of Table I may also be readily explained by the difference in the air pressures. The time required to fill the high pressure cylinder and the decay taking place during that time in the emanation introduced with the air preclude a comparison of the amounts of active emanation present in each cylinder when the first observations upon their conductivities were made; but if the amount in the high pressure cylinder were equal to or greater than that in the low pressure cylinder, the difference in the initial conductivities is explained, while, if it were less, the greater density of the air in the high pressure cylinder and the consequent greater absorption would still account for the higher conductivity.

IV. Effect of Different Metals.—To ascertain whether the conductivity of the air inclosed was affected by a change in the metal composing the walls of the receiver, linings of tin and lead were in turn fitted into the zinc cylinder used in the first experiment. Tests of the conductivity were made both with and without the tin and lead linings. Before each test the cylinder was well aired and sealed in the manner already described. As soon as the air was inclosed, measurements on the conductivity were begun and continued at stated intervals as before.

TABLE II.

Time.	Current: Zinc.	Arbitrary Tin.	Scale. Lead.
10 mins.	13.0	13.0	15.4
15 "	8.3	11.0	....
30 "	5.4	7.6	13.4
45 "	5.3	7.3	12.1
1.0 hours	5.0	....	11.55
1.5 "	4.85	7.2	10.8
2.0 "	....	7.3	11.5
2.5 "	....	7.3	....
5.0 "	5.0	....	11.8
7.0 "	5.3	....	11.9
9.0 "	....	....	12.0
12.0 "	....	7.9	....
18.0 "	6.0	8.0	....

The values obtained for the conductivity with each of the metals are given in Table II, and curves representing these values are shown in Fig. 4. The curves for the different metals, it will be seen, have the same characteristics. In each there is a rapid drop to a minimum and a gradual rise toward an ultimate limiting value. It is interesting to note that a considerable difference was found in the minimum conductivities for the three metals, and that the final limiting values also varied. The decay of an emanation introduced into the cylinders with the air would again account for the first portion of the curves, a radioactive emanation from the metallic walls would explain the existence of the second portion; while the differences in the minimum and limiting values may be considered to have their origin in variations in the rate at which the emanation is given off by the different metals. In this connection it will be noted that the limiting values of the conductivities range according to the atomic weights of the metals, lead having the highest, tin the next, and zinc the lowest.

V. Effect of Variations in Pressure.—In order to investigate the relation between the conductivity of air and the pressure at which it was confined, the heavy cylinder was filled to a pressure of about seven atmospheres and allowed to stand for some days until its conductivity assumed a constant value. The air was then allowed to escape gradually, and the pressure reduced from 501.0 cms. to 4.4 cms. of mercury, the conductivity being measured at these and at various intermediate pressures. The results are given in Table III, and the conductivity curve in Fig. 5.

TABLE III.

Pressure in Cms.	Current: Arbitrary Scale.
501.0	23.5
481.0	22.7
420.0	21.2
384.0	20.3
272.0	15.8
227.0	14.1
176.0	11.7
125.0	9.3
74.2	6.5
69.3	5.8
62.0	5.4
53.0	4.7
44.2	4.2
35.0	3.5
22.4	2.7
18.2	2.2
14.0	1.8
4.4	1.1

The ionization curve so nearly approaches a straight line that we may almost conclude, in view of the wide range of the pressures examined, that the conductivity was proportional to the pressure. This result is what we should expect to obtain with an emanation maintained at a constant strength and emitting a radiation of a penetrating nature.

VI. Penetrating Rays from External Sources.—While the effects described up to the present may be explained by supposing the ionization to be caused by a radioactive emanation sent off from the metals, it has been found that part of the conductivity cannot be accounted for in this way, but must be attributed to an active agent external to the receiver.

The heavy cylinder referred to above was filled with air to a pressure of about 400 cms. of mercury and allowed to stand until its conductivity had become steady. It was then placed in an insulated galvanized iron tank, 1.5 meters in height and .75 meter in diameter, which was gradually filled with water so as to surround the cylinder with a layer 25 cms. in thickness. The initial conductivity before the water was admitted was 21.1. As the water rose the conductivity decreased and fell to 13.3 when the tank had been filled. The values for the conductivity during the experiment are given in Table IV and are represented by the curve shown in Fig. 6. From these values it will be seen that the loss was almost directly proportional to the rise of the water, and that the total fall in conductivity was about 37 per cent.

TABLE IV.

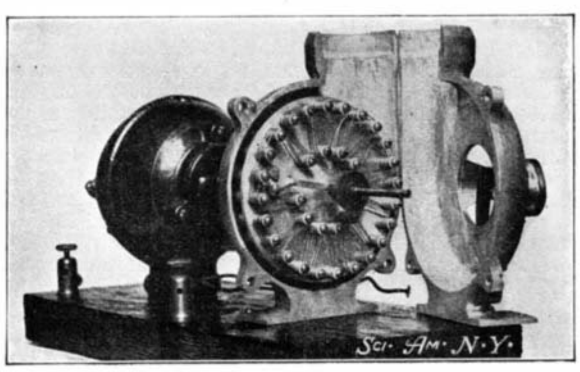
Depth in Cms.	Current: Arbitrary Scale.
0.0	21.1
15.0	20.5
60.0	18.0
77.0	17.0
97.0	14.3
110.0	13.75
120.0	13.3

The experiment was repeated with the cylinder placed in a tank 50 cms. in diameter. This tank permitted the cylinder to be surrounded by a layer of water 12.5 cms. in thickness, and it was found when the water was poured in that the conductivity fell off 17.5 per cent.

From these results it is evident that the ordinary air of a room is traversed by an exceedingly penetrating radiation, such as that which Rutherford has shown to be emitted by thorium, radium, and the excited radioactivity produced by thorium and radium.

In order to reach definite conclusions regarding the extent and true character of the effect of various metals upon the conductivity of the air which they inclose, it would be necessary to entirely cut off the inclosing vessel from the action of any external radiation, and the writers have not yet carried their experiments to this point.

* Phil. Mag., January, 1900, p. 6.

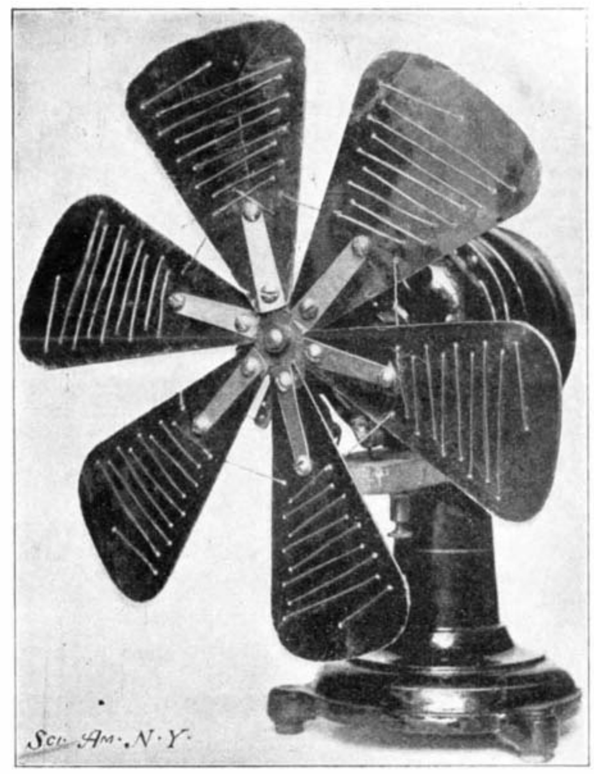


THE DE MARE ELECTRO-THERMIC FAN AND CASING.

THE DE MARE ELECTRO-THERMIC FAN.*

By EMILE GUARINI.

MR. DE MARE, a distinguished electrician of Brussels, has invented an electro-thermic fan. The apparatus consists of an electric motor and a rotating fan, the blades of which are of mica. Upon these mica blades are fastened resistance coils, which are heated by the passage through them of a current of electricity. The temperature of these coils should be carried as high as possible, first because the temperature of the surrounding medium—air—is increased, and again because the efficiency of the radiator is also augmented in this manner. Let us suppose the coil to offer a resistance equivalent to 100 ohms while a current of 10 amperes is passing through it. Joule's law teaches that the amount of energy consumed in the form of heat will be equal to the resistance multiplied by the square of intensity, which in the example above will be $100 \times 10^2 = 10{,}000$. If we double the intensity of the current and neglect the increase of resistance offered by the wire by reason of the elevation of the temperature at which it passes, we shall obtain the equation $100 \times 20^2 = 40{,}000$, which represents a fourfold development of heat. This, except in part, is not always exact; for the higher we raise the temperature, the more luminous does the resistance coil become and the greater will be the loss of energy. From experiments conducted during the last exposition at Antwerp, I learned that the glowing power of a resistance—the power sufficient to produce a certain degree of glow in a given coil—increases, in certain cases at least, with the sixth power of the intensity of the current, that is to say, if a given current be doubled, the luminous intensity will be 64 times as great. From this may be deduced that as far as electric heating is concerned, the ideal conditions would be those which, while setting the air in motion, would allow of carrying the resistance coils up to a very high temperature without producing luminous phenomena.



THE DE MARE ELECTRO-THERMIC FAN.

This is just the problem which De Mare has solved, and we give below the manner in which he has accomplished it. First of all, he made the following experiment. After raising the resistance coils to a white heat he started the fan, and I observed the interesting phenomenon that the turns of the coil nearest the center of the fan became black, viz., cooled down, while those situated nearer the outer edge or periphery remained in a glowing state. The faster the fan turned, the more marked was the phenomenon. It is explained in this wise: At the center an increase of pressure or extra density of the air was produced, while at the outer portion of the fan a certain rarefaction was generated. A second experiment was made with a platinum wire through which a current of sufficient intensity was caused to flow.

This wire fused in the rarefied air at the circumference, remained glowing in the air at ordinary pressure, but became black in the compressed air at the center, at the same time getting hotter. This rather paradoxical condition arose from the fact that while compressed air is a poor conductor of electricity, it is an excellent conductor of heat.

The wire alone produces the heat which is rapidly absorbed by the compressed air. This absorption of the heat by the air prevents the temperature of the wire from rising to the fusing point. From these experiments with the electro-thermic fan of Mr. De Mare it is but a single step to practical results. The inventor achieves this end by inclosing his radiating fan in a casing provided with an opening resembling that of an ordinary power blower. When the fan is in motion, the air is compressed in the casing.

The pressure of the air upon the resistance coils revolving in it is almost uniform at every point. When the fan turns and a current of electricity is passed through the coils, a very lively heat, an insupportable

* Specially prepared for the SCIENTIFIC AMERICAN SUPPLEMENT.