metal, as shown in Fig. 3, which is a perspective view of a motor, with sliding base and starting-box complete.

These machines are calculated to be equally efficient as dynamos, and are coming into use in many small isolated incandescent-light plants. For this purpose they are compound wound; and the regulation, it is claimed, is so perfect, that all but one lamp may be suddenly turned off without moving rheostat or brushes, and without noticeable change in the brilliancy of the remaining lamp.

THE LOUISVILLE TORNADO.

ONCE in a great while the whole world is startled by such an appalling catastrophe as the Chicago fire of 1871 or the Boston conflagration of 1872. Such disasters are entirely outside of the usual experience, and thus make a most profound impression. Of such a character are to be regarded the Grinnell (Iowa) tornado of April 17, 1882, and the more recent one at Louisville on March 27, 1890, in which 76 people were killed and $2,250,000 of property were destroyed. It might be thought that every tornado has exactly the same power, but does not show it because it does not happen to strike where it can do the most damage. To a certain extent we might argue in precisely the same way about a fire. Every fire, under such environments as mentioned above, would reproduce the terrible effects, but we find that the ordinary result of a fire is far different; and this is exactly the truth in regard to tornadoes. No two tornadoes are alike in their diameter or force. We may argue, however, that if two thousand tornadoes have produced one such as that at Grinnell, then we need not expect such a one again in about the same number, excepting as an increase in the size and frequency of towns in the tornado regions gives a more frequent opportunity for such accidents. This may also be said as true regarding the most serious fires.

Just preceding this tornado the atmospheric disturbance to the west and north-west of its development was unusually marked; so much so, that all the region in which the violent storms occurred were warned of their probable occurrence nearly twelve hours in advance by the Signal Office at Washington. The centre of the general storm at 7 A.M. (Central time), or twelve hours before the tornado, was in eastern Kansas, at which point the air-pressure was below 29.1 inches. At 7 P.M. this storm had moved rapidly to central Illinois, and just fifty-seven minutes later Louisville was struck and partly destroyed. This fact, that we have a chart of the meteorological conditions within an hour of this outburst, is very important. We find that the winds throughout the tornado region were from the south and south-east; and this current existed even up to the clouds, as we have determined in so many cases before. In fact, the whole circulation of the atmosphere was no whit different from that noted again and again in such general storms. The tornadoes were suddenly thrown into this atmospheric circulation almost without warning. The velocity of the general storm, moving nearly due east, was 38 miles per hour from 7 to 11 A.M. of March 27, 39 miles per hour in the next four hours, and 37 miles per hour in the four hours just

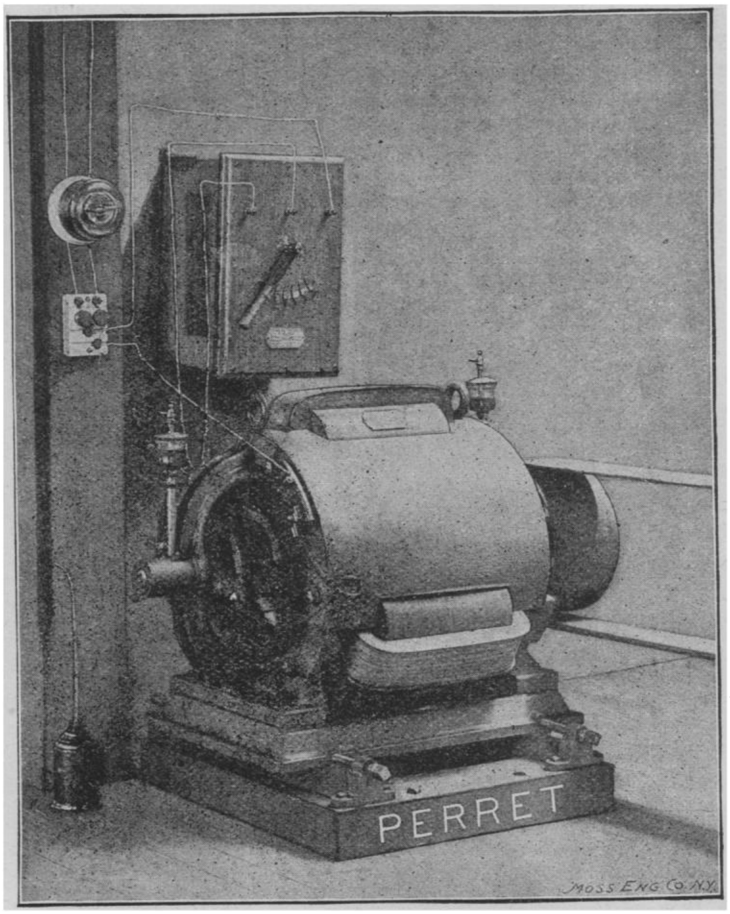

FIG. 3.—THE PERRET MULTIPOLAR ELECTRIC MOTOR.

preceding the tornadoes. It is a little difficult to obtain the exact velocity of the tornadoes, as the times are in most cases very indefinite; but the best authenticated times in the Louisville outburst would make it a little more than 80 miles per hour, the path being directed nearly north-east. There was a most remarkable series of tornadoes in this region, including southern Illinois and Indiana, western Kentucky, and just the northern border of Tennessee. The paths were all in a north-east direction, the earlier being 200 miles nearer the centre of the general storm, and much shorter than the later.

The first definite notice of a violent rush of air was at Mill Creek, Ill., at 4.30 P.M. This track (I) was very short, and is not traced outside of the town. Track II runs a short distance near Olney, Ill., and the time was 5.30 P.M. Track III was much the longest, and most destructive of all. It was first noted at 5.30 P.M., at Metropolis, Ill., and passed through or near the following towns (all in Kentucky), dipping now and then as it rushed onward at 80 miles per hour,— Hampton at 5.40; Marion at 6; Clay at 6; Dixon, Sebree, West Louisville, Delaware, Owensboro, at 6.17; Enterprise, Knottsville, Hawesville, Louisville, at 7.57,— and is last heard of in Jeffersonville, Ind., just across the river from Louisville. Track IV first appears at Farmington, Ky., and passes near Kuttawa, Eddyville at 6.30, Bremen, and Hartford, all in Kentucky. Track V is traced near Belleview, Caledonia, and Sinking Fork, in Kentucky. Track VI may possibly be connected with III, and is traceable near Eminence, Pleasureville at 8.30, La Grange at 8.50, Campbellburg, and Carrollton, all in Kentucky. Track VII passes near Rogana, Tenn., at 8.30; Eulia, Tenn.; Coatstown, Tenn., at 8.50; Dixon's Springs, Tenn. (probably); Butlersville, Ky.; and Glasgow, Ky., at 9. Track VIII is traced near Fayetteville, Fosterville at 9.15, Millersburg at 9.15, all in Tennessee. Track IX is near Rockcastle Springs, Ky., at 11. The last violent wind, or track X, is found at Marshall, Ky., at 8.30.

It will be understood, that, though all this region felt these violent wind-rushes, yet these paths are by no means continuous from town to town, and in most cases there was no serious damage. Louisville suffered the worst, as just noted. Outside of Louisville there were 59 killed and a property loss of $1,000,000. At Metropolis, Ill., 1 person was killed, 50 injured, and the property loss was $150,000. The most exaggerated reports of losses were circulated by the newspapers. One prominent Western paper, whose statement was widely copied by others, a whole month afterward placed the loss in Webster County, Ky., alone at 111, while the true loss was 8. In Barren County the loss was placed at 30, though no one was killed there. In Lyons County 23 killed were given, though but 2 died there. This same paper made no mention of loss of life in Livingston County, where 9 were killed, and in 6 other counties where an aggregate of 40 were killed. Of course, there was no intention of distorting facts in this case: it is given as a simple illustration of the great difficulty which inheres in studies of this kind, and the great danger there is in taking descriptions by two or more observers of the same destruction, and applying them to several places, and not to a single spot. The utmost care should be exercised in giving the exact place of the catastrophe, either as in a town or village, or so many miles in any direction, as the case may be.

While the names of a large number of towns have been given above as visited on this date, yet there were many others that could not be enumerated for lack of space: in fact, a thorough research would seek to establish exactly the spots where destruction was least, as well as where it was greatest. It is quite remarkable that though this whole region was in a disturbed condition, meteorologically speaking, yet there were enormous areas not seriously touched. A careful research would have developed some valuable facts; but, so far as known, the only outburst given a careful study was at Louisville. It is to be deplored that such a fine opportunity to add to our knowledge of these storms was lost. We may hope that in the near future such occasions will be seized upon as of the greatest importance. It is probable that the weather service of each State would be best suited to take up this study, and it is noted that the Ohio Weather Service has exhibited commendable zeal in this regard.

There has been published in the *Weather Review* a good description by Sergeant Frank Burke of the tornado at Louisville, Ky., and this will be freely quoted from. The times given are all reduced to Central. "At 7.30 P.M., although intense darkness precluded careful observation, the clouds in the south-west exhibited evidence of a most violent commotion. It appeared as though north-west and south-west clouds, in coming into contact, had been shattered to pieces, and their fragments, intermingling, had been thrown upward and laterally by the force of the shock. These movements occurred at a considerable elevation, the space between the clouds and the earth having a misty or fog-like condition. Heavy rain began almost at the moment of this commotion. At the same time the lightning-flashes, which had occurred hitherto only at long intervals, increased tenfold in frequency and intensity, the south-west quarter of the heavens being the centre from which the almost incessant flashes radiated. A peculiar feature of this display was the almost entire absence of thunder. The wind had been blowing a moderate breeze from the south-east during the afternoon. At 7.34 it shifted suddenly to the south-west, and increased in force. At 7.50 the rain had almost ceased. A few moments later, scattering hail fell, average diameter half an inch; then came a momentary lull in the wind, and a peculiar, indescribable oppressiveness of the atmosphere. The darkness was intensified at this moment by the sudden diminution of the gas-jets, which in many cases were extinguished. It may be important to state in this connection that the lights were not blown out, but failed through lack of pressure in the reservoir. The approach of the tornado was heralded by a tremendous roaring sound, mingled with the crash of falling buildings. The noise has been likened to that produced by the passage of a heavy train of cars over a bridge, a thousand times intensified. The storm struck the city at 18th Street and Broadway, crossed it in an almost due north-east direction, and at 7.57 left it at 7th and Water Streets. This time is verified by the telegraph officials, who noted it as the moment when their wires, which cross the tornado's track, ceased to work. Persons who saw the cloud coincide in stating that it was of a balloon or turnip shape, though the darkness and confusion precluded accurate observations of its movements. It was accompanied by a most terrific electric display, and several reliable persons assert that balls of fire were playing about it. The highest wind recorded at the Signal Office, less than 1,800 feet from the path, was 36 miles per hour. After it had passed, the wind shifted suddenly to the west, and continued to blow from that point for twenty-four hours, and with increasing velocity, the record showing 42 miles per hour at 9 P.M. The sky was perfectly clear at 9.30 P.M., except a streak of very high and apparently motionless cirrus in the west. Shortly after this time the atmosphere became obscured by a peculiar haze or smoke, through which the moon shone with a reddish light.

"Where the tornado entered the city, the width of the path was a little more than 600 feet. As the cloud progressed, the width of its path increased to 1,500. There is no evidence that the tornado-cloud touched the ground at any point in Louisville. In nearly every case the destruction was confined to the upper floors of the demolished buildings, but comparatively few houses being totally ruined; and also a large proportion of the one-story structures in its path were uninjured. Churches, halls, warehouses, and other structures having but little interior support, suffered the most. To this fact is attributed the principal loss of life. At the Falls City Hall alone, where a large number had congregated, 44 were killed. Frame buildings invariably withstood the shock much better than those constructed of masonry. But few of the destroyed buildings bear evidence of being actually blown down by the whirl of the tornado-cloud itself, but their destruction was apparently caused rather by a lateral or vertical rush of air-currents centring toward it. The ruins and the disposition of the *débris* give ample evidence of this. The right [south] side of the storm-track, and in a less marked degree the left side, afforded numerous examples of the intensity of this lateral force. In both cases [i.e., on either side of the track] the sides of the buildings facing the storm were pulled out, the *débris* falling towards it [the track]. In many cases fragile articles, such as glassware, remained undisturbed. In the centre of the track the destruction was mainly due to a vertical force which lifted the roofs of the buildings. The roof of the Union Depot was lifted bodily, and deposited intact on the floor, immediately beneath its original location.

"The destroyed buildings were, as a rule, of a very unsubstantial character, being mainly ordinary brick dwellings, small stores, and warehouses. The Fort Nelson building, at 7th and Main Streets, is the most notable exception to the general destruction in the tornado path. This is a well-constructed six-story building, and, by its greater height than those surrounding it, was more exposed to the storm's fury. Despite the fact that it was directly in the storm's track, and that all other houses on either side were wrecked, it escaped with the loss of its windows. The gyratory motion of the tornado is well illustrated in the disposition of the prostrated trees in the parks, and the timber outside the city. In the centre the trees were piled in promiscuous heaps, denoting a tremendous wrenching or twisting force. On the right side the tree-tops point almost north-east; those on the left side, nearer due east. Throughout the path of the storm the zone of destruction on the right [south] side is more than twice as wide as that on the left side, and shows a much greater intensity of force."

I have quoted almost the whole of Mr. Burke's most excellent report, which may be regarded as a model in its terseness and statement of valuable facts. One or two comments are added. The heavy rain preceding the tornado seems to have been independent of it, and not necessarily due to any action in it. The presence of lightning, and absence of thunder, are noteworthy, and may explain the fact that oftentimes no electric action is reported in a tornado. Thunder is always regarded as the most prominent characteristic in a thunder-storm. The sudden shifting of the wind to a direction from the tornado is very significant. How could this have been if there were a partial vacuum in the storm? The failure of the gaslights is very interesting, and at first sight appears to show a marked diminution in pressure. Diligent inquiry at a gas-office, however, shows that no reasonable diminution in the pressure of the atmosphere could affect a gaslight; moreover, this same phenomenon was noted at Cleveland, O, at a time when there was a very high wind, but no tornado. Investigation has shown that a high wind forces the immense gas-holder against the vertical posts, and this causes the failure in the pressure. This explanation is now accepted by those familiar with the subject. It seems also probable that such a high wind, when blowing near the earth, would have a tendency to an upward thrust; and this has been shown repeatedly by the uplift of dust, leaves, and small branches in front of a sudden gust. The increasing wind after the tornado was not connected in any way with that, but was simply the high wind in the rear of a storm, and in this case it was intensified by the steep barometric gradient. The preservation of the Fort Nelson building was probably due to a diminution in, or a lifting-up of, the storm just at that point, and not to its construction. There are innumerable instances in which the frailest structures have been left undisturbed in the centre of a tornado-track. The evidence from the prostrated trees does not bear out the gyratory theory, but is rather strongly against it. If there were any gyration, say, from right to left, the trees on the left (north) side ought to face west, and not east as they were reported.

Mr. Burke, in a private correspondence, states that he made a most diligent search for evidence of corks being blown from bottles, but did not find a single case, although there were several apothecary-shops and bottling-establishments in the centre of the track. He also states that the diminution in the gaslights was quite sudden, and passed away quickly. It would be interesting if some one would determine the velocity of the wind needed to produce this effect. This report must be regarded as corroborative, and not as absolutely establishing points now in doubt. The statements in the report show only very slight evidence of bias or leaning toward any theory; and this is just what is needed now, if we are to make any headway in our studies. The report is worthy of commendation.

Incidentally one of the more interesting facts brought out by the tornadoes on this date are barograph traces made by the passage of the tornado at Owensboro, Ky., and Cincinnati, O. These are given in the accompanying plate, Figs. 6 and 7. Unfortunately the original trace for Fig. 6 was carried by the owner to Scotland, and given to Mr. Buchan, who rightly regarded it as a most valuable acquisition. It is to be regretted that the original was not kept in this country, where it belongs, and a copy taken abroad. The copy

I have, however, is a fair representation of the original. I have enlarged Figs. 5, 6, and 7 from the Richard barograph to make them directly comparable with the barograph sheet at Washington, given in Fig. 8. The barograph at Owensboro was a mile and a half from the nearest point of the tornado. It has been supposed all along that a tornado could not produce any effect on pressure more than a few hundred feet from its centre, but here seems to be good evidence of an effect over 7,000 feet away. The first sudden drop of the curve with an immediate return is a little singular, and appears like the sudden drop found by others, and explained by the effect of the wind. Whatever may have caused this drop, there is no doubt of the rise after it;

FIG. 5. FIG. 6. FIG. 7. FIG. 8.

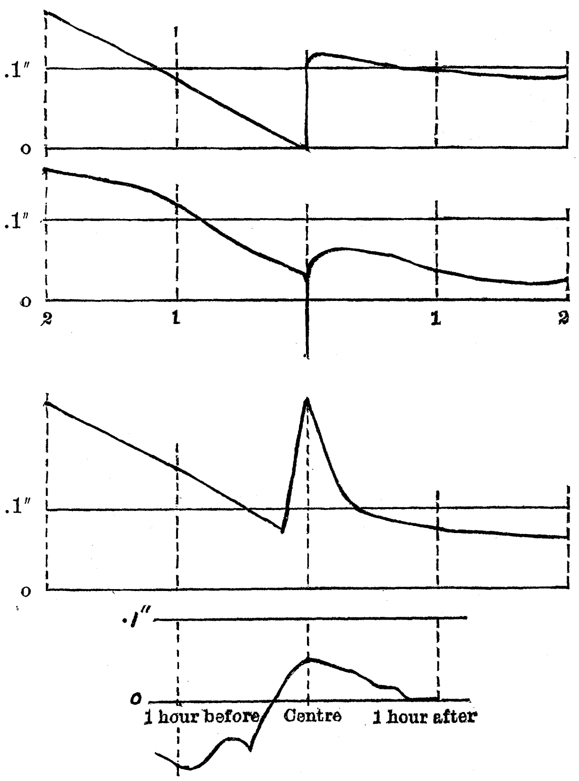

Fig. 5, tornado St. Louis, Mo. (Jan. 12, 1890, 5.16 P.M.); Fig. 6, tornado Owensboro, Ky. (March 27, 1890, 6.17 P.M.); Fig. 7, tornado Cincinnati, O. (March 27, 1890, 8.20 P.M.); Fig. 8, thunder-storm Washington, D.C. (June 22, 1890, 9.8 P.M.).

and this rise is far more striking at Cincinnati, where the storm crossed 59 minutes after leaving Louisville. Fig. 5 is also given from the barograph at St. Louis during the tornado of Jan. 12 of this year. This has already been referred to. There is no doubt of a marked rise here. Fig. 8 is a portion of the pressure-curve made at Washington, D.C., during the prevalence of one of the most severe thunderstorms that has visited the station. There was a steady rise for an hour, and a less rapid fall after the centre had passed. This storm came up and passed off very slowly, and was attended by most brilliant lightning and a terrific wind. The general similarity in these curves, excepting Fig. 6, is very striking. We may hope to get more of such curves on both sides, and possibly in the centre of tornado-tracks.

Instructions for Observing Tornadoes.

If any one thing has been emphasized in these pages, it has been the extreme need of more light on this whole question. The earlier investigators of the phenomenon were untrammelled, to a large extent, by preconceived opinions, and it must strike every one that few substantial facts unknown to them have been brought out since their time. It is to be hoped that the number of those willing to aid in establishing the facts and ferreting out the mysteries will be largely increased, and it is for such these instructions are given.

1. It is very essential that one divests himself of every preconceived notion about the whirling, sucking, or any other action of a tornado. There is the utmost danger of seeing the tornado do what we think it ought to do. It would be far safer, if one has an inclination to such views, to deny that such a view is correct, and only to accept it after most incontestable proof.

2. Note the time of day carefully, and specify whether the time used is Eastern, Central, Mountain, or some city time.

3. The side of the track on which the observer stood should be given.

4. Note the appearance of the clouds in the distance,— whether they roll upward, come together from the north and south,— or any other phenomenon connected with them.

5. Special note should be made of a cloud of dust and its general appearance.

6. See whether the funnel-cloud is visible at a distance, or suddenly breaks into view on the approach of the tornado. If possible, locate the first appearance of the funnel by a tree, house, or object close by, and, after the tornado has passed, measure the distance from the observer's position to that of the tornado when first seen.

7. If the observer is a thousand feet or more away from the funnel, or cannot see distinctly trees or objects in it or near it, he should not try to make detailed observations of the whirl, or any thing else at the tornado. Fix the attention on the motion of detached clouds. Make every effort, by comparison with trees and houses between the tornado and the observer, to get its height, width, and speed: these can be much better found out at a little distance than close to the cloud.

8. Make careful observations of all electric displays, the appearance of balls of fire, the sound of thunder, the roar of the tornado, etc.

9. If the observer is within a hundred feet of the tornado on the north side, he need have no fear, and may carefully examine all objects flying just above the ground. He should note carefully the foot, the middle, and the top of the funnel, to see whether any tree or object is carried to his right as he faces the funnel.

10. Note also whether any object is carried up straight in the funnel, or whether it is borne along in the swift wind. If there is an uprush in the tornado, it ought to be easily told; and the appearance will be very different from that if the object or house is borne along by the wind, and afterward inclined upward. If there is a sort of explosive effect, the upward motion will be more or less jerky, and not steady as in a stream. On the whole, the evidence seems to show something like an uprush, though it seems conclusive that this is not due to a vacuum in the tornado, as many think. It is very plain that nothing can be sucked into the tornado, because of a partial vacuum there; but if it rushes in or up, it must be borne or propelled by a stream of electricity, so to speak, or by a rush of air. One of the best illustrations of

this has just come to hand from the storm at Bradshaw, Neb. This tornado passed over a tank ten feet long, three feet wide, and twenty inches deep, full of water. This tank was air-tight, and had an opening in the top one foot square. The observer reports that the tornado sucked all the water out of this tank. A moment's reflection will show that this could have been done only by the insertion of the funnel into the opening one foot square. Of course this is absurd, and we must resort to some other explanation of the phenomenon.

11. After the tornado has passed, note the appearance of the houses for explosive effects.

12. Pay particular attention to the direction of the trees, making a separate observation on the south side, in the centre, and on the north side. See if any *débris* or objects have been carried in any case toward the west or south-west on the north side of the track, and measure the distance.

13. A note should be made of the width of the greatest destruction, not including houses unroofed on the borders; also the length of the path where it was most destructive, and the distance from the point at which it first struck the earth to the point at which it left the earth during the time of the greatest destruction.

14. Give the names of persons killed, if any.

15. Give an estimate of the loss to buildings, also specifying the number of buildings destroyed and their characters as to strength, etc.

16. A note should be made of the rainfall,— whether it was most abundant before, during, or after the tornado; also, if possible, the amount of rain at the centre of the track and at some point two thousand or three thousand feet on either side.

17. Careful note should be made of hail, size of stones, width of track, situation with respect to the main track, etc.

18. After the tornado the direction of the path should be most carefully determined.

19. All evidences of corks flying from bottles should be carefully looked for.

20. If one has a barograph, its record will be of the utmost value. If one has a barometer, an observation should be made by some one every minute till the tornado has passed. If the barometer is an aneroid, the face should be gently tapped before each observation. A steady watch of the needle may show any sudden fluctuation too rapid to be caught by reading the barometer. This instrument may be read in a dug-out or a cellar as well as in a house.

Of course, every one will keep eyes and ears open for any and all phenomena to be noted in this remarkable outburst.

H. A. Hazen.

NOTES AND NEWS.

In *Science* of July 25, second column, 36th line from the bottom, "*cenoreus*" should read "*cinereus*."

— A census taken in St. Petersburg in December, 1889, proved that during the previous twelve months the number of inhabitants had increased by 25,006, and had attained to a total of 1,003,315, says *The Scottish Geographical Magazine*. Attention is drawn to three noteworthy points regarding the population: the first is that the increase is greater in the suburbs than in the heart of the city; in the second place, the ratio of women to men has increased during the last twenty years, probably in consequence of a greater demand for female labor; lastly, since 1885 the births have been more numerous than the deaths, by 2,750 yearly.

— Some discussion has been going on in Ceylon over the question of the language spoken by the Veddahs, the aborigines of that country. The subject, says the *Colonies and India*, would seem to be one well worthy the attention of philologists; and the brothers Sarasin, who have been pursuing their anthropological researches in Ceylon, express the opinion, that, if a philologist were to take the matter up, great service would be rendered to all those engaged in the work of scientific research in the island. Tennant says of the Veddahs (*Nature*, July 17), "Their language, which is limited to a very few words, is a dialect of Singhalese without any admixture from the Sanscrit or Pali, — a circumstance indicative of their repugnance to intercourse with strangers." Professor Schmidt of the Leipzig University, who visited the Veddahs last year, says, "Their language is similar in construction to the Dravidian languages, — that is, similar in grammatical construction,— but they have adopted a great number of Singhalese words," which enabled him to hold converse with them by means of a Singhalese interpreter. The Drs. Sarasin also managed to make themselves understood by means of Singhalese.

— A recent exhibition of electrically deposited copper in London, England, attracted much attention from persons interested in the use of that metal, particularly for steam-pipes and electric conductors. There were shown copper pipes of all sizes, from 6 inches to 18 inches in diameter by about 10 feet in length, and ranging from one-sixteenth to three-eighths of an inch in thickness. They were prepared by an electrical copper-depositing process, on a commercial scale, from common Chili bars without any intermediate process. The bars are placed as the anode in an electrolytic bath, and the tubes are deposited direct on a rotating mandrel, each individual atom of metal being rubbed into those surrounding it by an agate burnisher. The result is a metal having a tensile strength of 25 tons per square inch, with 20 per cent elongation, and of such purity that when drawn into wire it has an electrical conductivity of 104, or 4 per cent better than the standard. This metal is so ductile that it can be drawn down, without any annealing whatever, till it takes forty miles to weigh a pound.

— The Engle garbage-cremator, which has been illustrated and described in these columns, is being successfully introduced in various parts of the country, especially in the South. In Tampa, Fla., one has been constructed of a capacity sufficient to dispose of that city's refuse. An official test, made previous to formal acceptance of the cremator by the authorities, was described in a recent issue of the Tampa *Tribune*. According to that paper, an accurate account kept, showed that in about seven hours' actual running time the furnace destroyed twenty cubic yards of night-soil and garbage, much of the latter being completely saturated with water, and containing large quantities of melons and melon-rinds. The fuel used was light wood, of which about one-quarter of a cord was burned, and three-quarters of a cord of slabs and waste refuse lumber. As nearly as can be stated, the operation of the furnace showed that it would destroy at least forty cubic yards of material in twelve hours, and would require about three-quarters of a cord of light wood during that time. The furnace has been formally accepted and paid for by the city, and will at once be put into active use.

— The council of the Scottish Meteorological Society refer, in a report made July 14, to the observations of Mr. Rankin on the number of dust-particles in the atmosphere, carried on with two sets of apparatus invented by Mr. Aitken. *Nature* states that, though it would be premature to offer a statement of positive results, the council think that some interesting conclusions appear to be indicated by the observations. The maximum number of dust-particles in a cubic centimetre hitherto observed is 12,862, on March 31; and the minimum, 50, on June 15. On March 31, at 4 30 P.M., the summit was clear, and the number of particles was 2,785; but shortly thereafter a thickness was seen approaching from south-west, which by 6 P.M. reached the observatory, and the number of particles rose to 12,862. On June 15 many observations were made during the day, when the number of particles fell from 937 at midnight, to 50 at 10.30 and 11.42 A.M. The observations point to a daily maximum during the afternoon