resistance of air alone, apart from the frictional resistances, would not be less than 1700 horse power. Though there is nothing to prevent the construction of electric locomotives capable of developing this or even greater power, the strength of the materials at present at command will set a limit to the speeds which may be obtained.

In order that the engineer may realise the imperfection of all his works, it is well for him to be constrained from time to time to contemplate the amount of energy involved in his final purpose compared with the energy of the coal with which he starts. I have endeavoured to put before you to-night the losses that occur and the reasons for them, in some steps of the complex machine which constitutes an electric railway, so in conclusion I will draw your attention to the ultimate efficiency of the machine, starting with the coal and ending with the passenger carried through space. The diagram on the wall, starting with the familiar 12,000,000 foot-pounds, the energy of a pound of coal, shows the loss in each step, supposing it made with the most economical appliances known to the engineer, first in the boiler, then in the steam engine, generator dynamo, conductors, locomotives, in the dead weight of the train, till finally we arrive at the energy expended on the passenger himself, which we find to be 133,000 foot-pounds, or but little more than 1 per cent. of the energy with which we started. It is true indeed that transportation is a more economical process than lighting with incandescent lamps, in which the final efficiency is about one-half per cent., but whether in lighting or in traction, when we consider that ninety-nine parts are now wasted for one part saved, we may realise that the future has greater possibilities than anything accomplished in the past.

HAIL STORMS.[1]

SOME recent thunder and hail storms were so violent that they call for more than a passing notice, not only on account of their severity, but also because they are well marked phenomena in our weather. The district in which they were most severe is that around Narrabri, and the weather map for the day indicated this district as one in which storms would probably manifest great intensity. The places from which the best accounts have reached me are Narrabri, Avondale, thirty miles due north of Narrabri, and Tulcumbah, fifty-seven miles south-east of Narrabri.

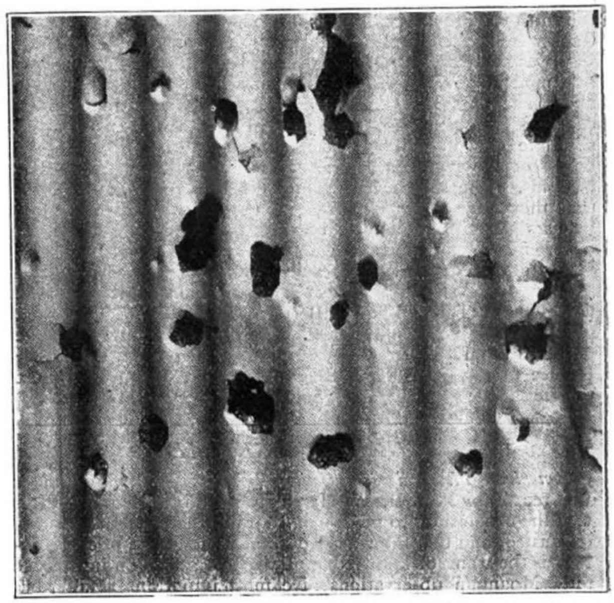
The Sydney weather chart at 9 a.m. on October 13, the day of these storms, shows us that there was but little difference in pressure all over Australia. To the west of the overland telegraph line it was slightly higher, over western New South Wales and Queensland lower, and higher again over the East Coast, in which the isobars clearly outline the area of relatively low pressure, and the kinks in them indicate disturbed conditions, local short-lived storms, and before the day was over the inference from the state of pressure was fully justified, for storms of extreme violence occurred over the area; storms which swept down great forest trees two and three feet in diameter. What this means in wind velocity I am unable to say, the trees are eucalypts, and therefore the wood is hard and very strong, but they were treated as if they were reeds, and their strength was as nothing compared with the force of the wind.

These storms are common enough, but owing to the sparse population they seldom pass over towns or dwellings. In this instance such has been the case, and in the future as population increases similar cases must increase in number, for the storms are abundant, indeed these storms form a well-marked feature of our summer weather. As a rule they are disconnected, and the most violent part of the wind covers but two hundred or three hundred yards wide, and travels along with great rapidity, leaving a narrow line of destruction in its wake.

On the day in question heavy storms were reported at Goodooga, Armidale, two hundred and forty miles south-east of Goodooga, and at Grafton one hundred miles north-east of Armidale. Storms which seem to have been quite disconnected, for the earliest time was at Grafton, and as a rule they come from the west; these are spoken of as severe storms, but were evidently not specially remarkable, nothing to compare with those in the Narrabri district to which I wish to direct your attention. Unfortunately, data for determining the rate of progress is not available, although that as to the intensity of the storms is abundant. I may mention that three days before these storms, that is on October 10; a similar storm passed over from Wilcannia to Sydney, a distance of four hundred and eighty miles, at the rate of fifty-five miles per hour; and I have before traced one over the same part of the colony, the rate being fifty-seven miles per hour, but we have not traced a sufficient number to determine an average rate.

As to the velocity of the wind along the line of damage in these storms, we have no actual anemometer results, so far we have not had one which passed over one of the anemometers, but judging from the damage done to large and solid trees, two and even three feet in diameter, it cannot I think be less than one hundred and forty or one hundred and fifty miles per hour.

We may now turn to the storms in the Narrabri district. The storm reached Narrabri at 6.15 p.m., and the postmaster reports that the storm which approached Narrabri from north-west was accompained by thunder and lightning, but no hail. The wind, however, seems to have been of hurricane violence, trees two feet in diameter were torn up by the roots, limbs twelve inches through were snapped off short, a brick factory completely ruined, roofs, sign-boards, and everything that the wind could move went flying; in the language of the local newspaper, "substantial brick buildings came tumbling in all directions, the



Photograph of iron perforated by hail.

air was full of iron tubs, galvanised iron, and tins of every description."

In the district south of Narrabri the storm was even more severe. At Tulcumbah Station, fifty-seven miles south-east from Narrabri, at 8 p.m. on October 13, a violent thunder and hail storm broke over the homestead. It lasted half an hour, and Mr. A. D. Griffiths, my informant and manager of the station, says, "I measured some of the hailstones, six and a half inches in circumference; this was fifteen or twenty minutes after the storm, and I think I did not get the largest. Next morning I found that nineteen sheep had been killed by the hail, also birds, kangaroo-rats, and other animals were found lying dead in all directions. All the windows exposed to the storm were broken, and the galvanised iron roofing is dented from end to end, and many sheets cut through: in several cases the hailstones went through the iron; in one sheet I found thirty holes, and in another more than sixty. The bark of the trees in the storm track was all battered by the hail, and the fences and buildings bore traces of the impact of these great lumps of ice. The stones were generally triangular or conoidal in form, many having an uneven surface, which looked as if it had been formed from frozen drops of water collected into masses; others had an opaque snow-like centre, perhaps the majority were like this, the remainder being like clear ice. It was only the larger stones that were irregular as described, the smaller ones were generally rounded."

At Avondale, thirty miles north of Narrabri, my informant,

[1] Read by H. C. Russell, F.R.S. before the Royal Society of N.S. Wales, November 2, 1892.

Mr. S. J. Dickson, says, "From the 9th to the 13th of October, the weather was unusually oppressive with threatening storms, and on the evening of the 13th a heavy storm was seen to be working up from the west accompanied by incessant lightning of every description, and about 8 p.m. it broke over the homestead in all its fury, the wind was from south-west and of terrific force, and the rain and hail were very severe. The hailstones were as large as hen-eggs, and in some of the paddocks, one particularly, it pounded the herbage completely out, so that not a vestige of it was left, although before the storm came on it was from six to twelve inches high, and in other places strong variegated thistles three to four feet high were beaten down. Trees some two feet thick, that the wind could not tear up by the roots, were snapped off short as if made of matchwood. In the storm the hail killed birds innumerable, and even domestic fowls roosting on the trees were killed by it, and after the storm a large snake was found cut into two pieces by the hail, so at least it appeared. On the open plain the hail laid four to six inches deep, and the whole country looked as if a heavy snowstorm had passed over it. Trees in the track of the hail were completely denuded of leaves, and the bark knocked off tree trunks and limbs. The storm wind carried away outstations, unroofed the hayshed, damaged the woolshed, and carried away two sides of the house-verandah, and the sheets of iron from it were found nearly half a mile (30 chains) away to the north-east, round wall plates in the hayshed six to eight inches thick were broken to pieces, and the iron roofing on all the buildings was battered by the hail as if some one had pounded it with a hammer all over. The storm track was only a mile to a mile and a half wide, at least the hail part. Between 7 and 8 p.m., as the storm came up, there seemed to be a white bow in the sky, like a white rainbow stretching from north to south. I have seen heavy storms before, but I never wish to see another like this. The shearers were completely terrified, and all say that they have never experienced a storm like it, in fact, it beggars description and can hardly be realised. It was an experience that we shall remember as long as we live."

North of Narrabri, and especially between Narrabri and Avondale, the storms were very severe. Midway between these places and at Terry-hi-hi and Berrigal Creek the wind worked great destruction in the forest. How violent it was may be gathered from the fact that great trees twelve feet in circumference at three feet from the ground, were snapped off short ten feet above the ground, or entirely stripped of their limbs.

SCIENTIFIC SERIAL.

American Meteorological Journal, March.—Exploration of the free air, by Prof. M. W. Harrington. The author considers that the conclusions to be drawn from weather maps are nearly exhausted, and that the reason of the imperfection of meteorology is the want of knowledge of what is going on in the free air. Mountain observations give most important results, but they are still surface observations. We know what goes on at the base of a cyclone, but not what occurs at the top. Theories are deduced from cloud observations, but we lack actual knowledge of what is going on above, and the only means available at present is systematic balloon observations. Prof. Harrington thinks that such observations should be provided for by funds from private sources.—The general winds of the Atlantic Ocean, by Prof. W. M. Davis. The basis of this discussion is the "Sailing Directory of the Atlantic Ocean," published by the Deutsche Seewarte, and especially two generalised wind charts contained in the atlas accompanying that work. The author classifies the winds as planetary (due to the earth's rotation and the influence of the sun), terrestrial (the annual migration of the wind belts north and south, and the seasonal variations of velocity and direction), including the interruptions of continents and mountain ranges.—The colours of cloudy condensation, by Prof. C. Barus. The author considers the problems connected with the condensation of water from moist air, and reviews the labours of Mr. Aitken and Mr. Bidwell with reference to the particles of an opaque steam-jet. He also gives a minute description of the apparatus employed in his own investigations.

SOCIETIES AND ACADEMIES.

LONDON.

Physical Society, March 24.—Prof. A. W. Rücker, F.R.S., President, in the chair.—Several excellent photographs of flying bullets and of the air waves produced by vibrating hammers, were exhibited, the originals of which had been taken by Prof. Mach.—A paper on the differential equation of electric flow was read by Mr. T. H. Blakesley. The object of the paper is to show that the ordinary mathematical expressions for electric flow fail to explain all known facts, and to point out that in order to interpret these facts certain properties of matter not usually recognised must be admitted. The subject is treated both algebraically and geometrically, in the latter case the magnitudes being represented by the projections of the sides of a triangle revolving in its own plane on a fixed line in that plane. Taking the ordinary differential equation for a simple circuit having resistance and self-induction, viz., $V - L\frac{dC}{dt} = RC$, it is shown that this takes no account of any energy except that spent in heating the conductor, and that where radiation into space is concerned, it is necessary to introduce another term λC, where λ is a quantity of the nature of resistance. It is further pointed out that if work be done outside the circuit, the line which geometrically represents the induced E.M.F. cannot be perpendicular to that indicating the current and "effective" E.M.F., the latter term being defined to mean the value of the quantity which is numerically equal to the product of the current into the resistance. A magnetic phase-lag must therefore exist. The author also shows that a magnetic field induced in phase with the magnetic induction would not result in a loss of energy, and no hysteresis could exist. Under the same circumstances there could be no radiation of energy from an alternating magnet. A Leyden jar discharging through a circuit having self-induction is next considered. Taking the ordinary premises, it is shown that no provision is there made for energy radiated into space, and that magnetic lag is necessary for the existence of such phenomena. The differential equations for the variables in condenser discharges according to ordinary assumptions are shown to be of the same form, and the variables can be represented by the projection of the sides of a triangle which is simultaneously undergoing uniform rotation and linear logarithmic shrinking. The rate of shrinking is the same as that of the radius vector of an equiangular spiral of characteristic angle β, where $\cos\beta = \sqrt{\frac{K}{L}} \cdot \frac{R}{2}$; K, L, and R representing capacity, self-induction, and resistance respectively. The equations and their consequences are considered at some length, and several important properties brought out. To allow for radiated energy, R must be virtually increased from R to $R+\lambda$, and the total energy is divided between the circuit and the field in the ratio of R to λ. If, therefore, the circumstances be such that λ is large compared with R, say by having high frequency, the heating of the circuit may only be a small part of the total energy. In this direction the author thinks the true explanation of some of Tesla's experiments is to be found, the energy being expended chiefly in radiation and not in current through the experimenter's body. Prof. Perry thought the C^2R term would not represent the heating of the wire when the oscillations were rapid, owing to the distribution of current not being uniform over the section of the conductor. Maxwell had shown that certain throttling terms had to be considered. In condenser discharges the complete equation would have many terms. Prof. O. J. Lodge said the best definition of R in such case. was that derived from Joule's law rather than that of Ohms Frequency was very important in the radiation of energy, but even at ordinary frequencies of alternators some energy was radiated. Referring to Tesla's experiments, he said the reason why no serious consequences followed, was that there was not much energy behind them. High frequency might be instrumental in preventing injury, but this he thought remained to be proved. Dr. Sumpner pointed out that losses other than C^2R (R being the ordinary resistance of the conductor) had to be taken into account. In some cases, such as transformers on open circuit, the effective resistance might be 1000 times that of the coil. To discuss completely the problem taken up by Mr. Blakesley, it would be necessary to take account of non-uniform distribution of current, both across and along the conductor, as well as the character of the magnetic and electric fields surrounding the circuit. Mr. Swinburne thought there was a tendency to over-estimate the rate of high-frequency currents, for unless the coils of transformers were assumed geometrically coincident, calculations were difficult. Errors of hundreds per cent. were quite possible. In Tesla's experiments no great power was involved, for the transformer could not give out any large power. Mr. Blakesley, in reply, said the