THE MAGNETIC STORM OF FEBRUARY 13, 1892.

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The facts which have led to the connection of disturbances on the sun with magnetic and electrical storms on the earth have been added to by the simul-

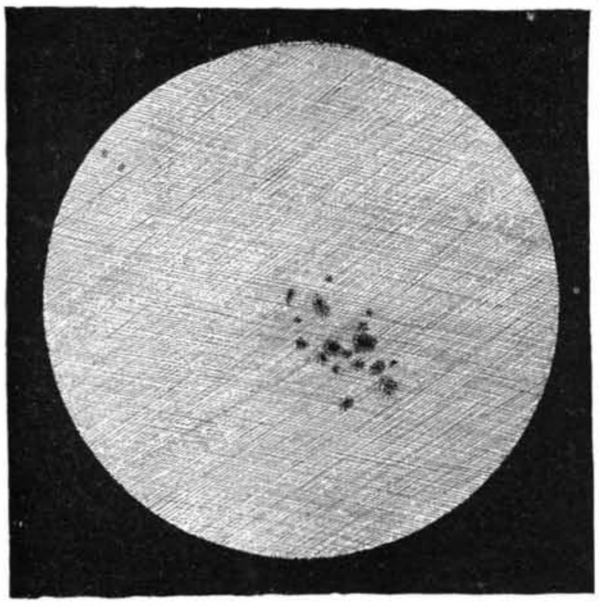

Fig. 1.—SUN SPOTS AS SEEN THROUGH THE 9·6 INCH EQUATORIAL AT THE NAVAL OBSERVATORY, FEBRUARY 13, 1891.

(Drawn from a photograph by J. A. Hoogewerff.)

taneous occurrence, in February of this year, of these phenomena on the two bodies which, though separated by a distance of 92,000,000 miles, seem to be in close sympathetic connection.

On February 12 there was published in the papers throughout the country an announcement of the appearance of a large spot on the sun. Through a piece of glass smoked over the flame of a candle, so as to diminish the intensity of the sun's light, this spot appeared as a nearly circular black speck, which, though small, could be distinctly seen. The telescope resolved it into a group of spots of immense extent, covering an area of about 140,000 by 100,000 miles, which, roughly speaking, is 140 times the total area of the earth.

Following this outbreak on the sun there appeared on the morning and evening of February 13 magnificent displays of the aurora borealis, visible generally throughout the northern part of America and Europe, which were accompanied by more or less derangement of telegraphic communication. The morning aurora was not generally noticed, but, in the evening, shortly after sunset, the northwestern sky was so vividly illuminated by a rosy glow that it was at first mistaken for the reflection of a distant fire. The rapid changes in its appearance soon showed its true character. Pulsating beams of greenish white light shot through the red up into the sky, transforming its dull glow into the ever-changing beauty of an aurora. "And now the northern lights begin to burn, faintly at first, like sunbeams playing in the waters of the blue sea. Then a soft crimson glow tinges the heavens. There is a blush on the cheek of night. The colors come and go, and change from crimson to gold, from gold to crimson. The snow is stained with rosy light. Twofold from the zenith, east and west, flames a fiery sword; and a broad band passes athwart the heavens, like a summer sunset. Soft purple clouds come sailing over the sky, and through their vapory folds the winking stars shine white as silver."—Longfellow.

The superstitions which formerly regarded these and other unusual phenomena as signs of approaching calamity are nearly outgrown in this scientific age, yet they still tinge the impressions of one who sees them for the first time.

From the fact of the appearance of the spots and auroræ, evidences of a magnetic storm were confidently looked for; and, upon developing the photographic record at the U. S. Naval Observatory, these expectations were fully realized. The records show graphically the direction at any moment of magnets so suspended that their movements are determined by the changes in the direction and intensity of the earth's magnetic force.

The action of the earth on a magnet can be roughly explained by imagining that at its center is a magnet whose axis is slightly inclined to the axis of the earth. A magnet develops in the space around it lines of force, one of which may be briefly defined as being the path which a single free magnetic pole would follow after being placed in it and subjected to the influence of the magnet. It is practically impossible to get a single magnetic pole, as such poles always exist in pairs, and no matter into how small pieces we may break a magnet, each piece has two poles, which have opposite effects, the one attracting and the other repelling a given pole of any magnet which may be brought near them. As the amount of this attraction or repulsion is greater the less is the distance separating the poles between which it is exercised, the result is that when two magnets are placed near each other they will, when free to move, place themselves so that their unlike poles are together. In the case of the imaginary magnet at the center of the earth, and any magnet on its surface, the length of the magnet is so small, compared with its distance from the center of the earth, that its two poles are at practically the same distance from either magnetic pole of the earth; and the magnet, if free to move, simply turns so as to set itself in the direction of the line of force created by the earth at that particular place. In the figure representing the earth (Fig. 2) *n s* is the magnet at its center, and the dotted lines are the lines of force produced by it. A single free north magnetic pole, if placed at A and free to move, would take the path A W *s*, while a free magnet (having, of course, two poles) would place itself along this line of force. A number of magnets are represented by *n' s'*, and each shows roughly the position which would be taken at that part of the earth by a magnet hung from its center of gravity, but free to turn in any direction. If there were a number of magnets floating around in the air, each magnet would turn until its poles were in the line of force which passed through its center. It will be seen from the figure that the magnets, besides pointing in a north and south direction, all have, except near the equator, a dip toward the center of the earth, while at the poles they are vertical.

It must not be taken for granted that there is such a magnet at the earth's center, or that the existence of it there would account perfectly for all the known

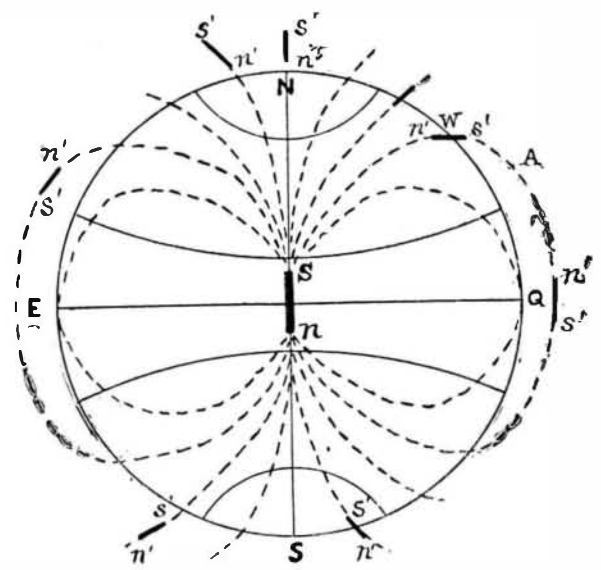

Fig. 2.—LINES OF FORCE PRODUCED BY THE EARTH CONSIDERED AS A MAGNET.

facts concerning the lines of force surrounding the earth; but it would simply account for there being such lines. As a matter of fact, the forces produced by a magnet may be duplicated by electric currents arranged in the proper way, and a system or systems of electric currents circulating in the earth and its surroundings can be imagined which will account very satisfactorily for the influence which we know to be exerted on magnetic needles at or near the earth's surface.

These lines of force which we know to exist are subject to changes both in direction and in amount of their influence on magnets.

The magnetic department at the U. S. Naval Observatory in Washington was established for the purpose of measuring and recording these changes. The apparatus (Figure 3) consists of three magnets, to each of which is fixed a small mirror from which a beam of light is reflected on to a strip of sensitive photographic paper placed on a revolving drum in a dark box. As long as the magnets remain stationary the revolution of the drums causes the light to make a straight line on the paper, but a motion of the magnet changes the line into an irregular one, the distance of which from the straight line shows the amount of the movement of the magnet. One of the three magnets is hung by a silk thread so as to be free to swing round in a horizontal plane. This magnet takes the horizontal direction of the lines of force, being practically a very sensitive compass. The second magnet is also horizontal, but is suspended by two platinum wires which are fastened to it a short distance apart. By turning the bar to which the upper ends of these wires are fastened, the magnet is twisted around until it points east and west, in which position it is most susceptible to the force which tends to make it point north and south. An increase in this force twists it one way, and a decrease of the force allows the wires to turn it slightly in the other direction. To appreciate the minuteness of this force one has but to turn a compass needle with his finger; and yet upon it depends

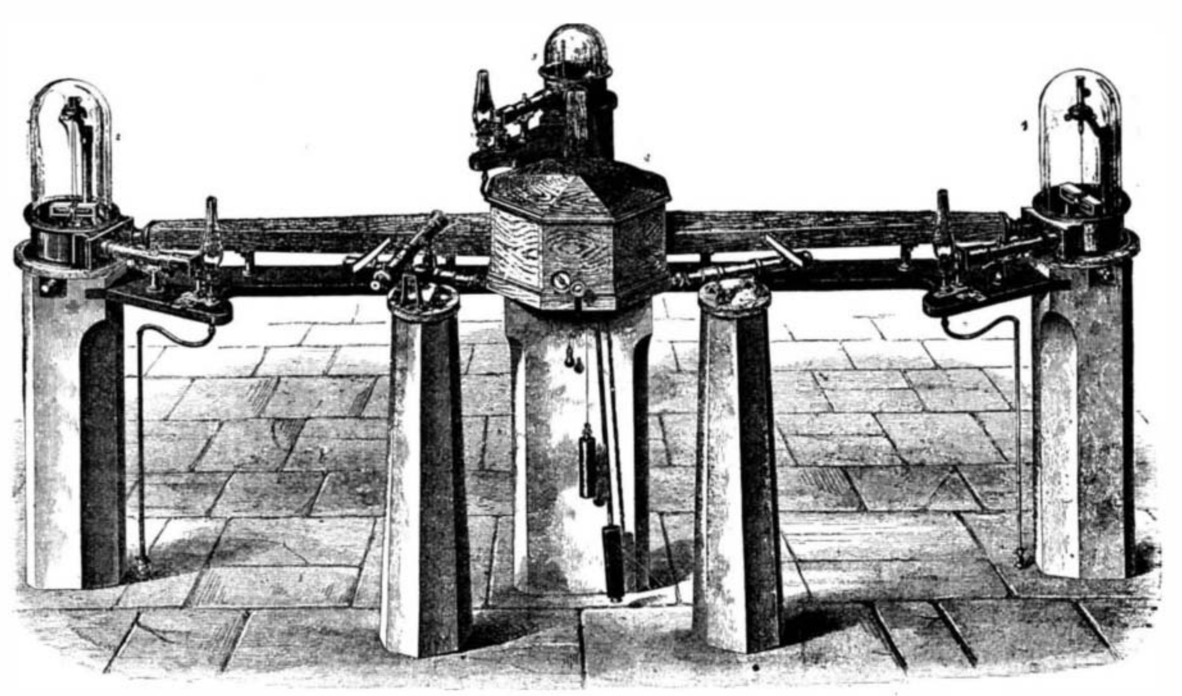

Fig. 3.—KEW MAGNETOGRAPH IN USE AT THE NAVAL OBSERVATORY, WASHINGTON.

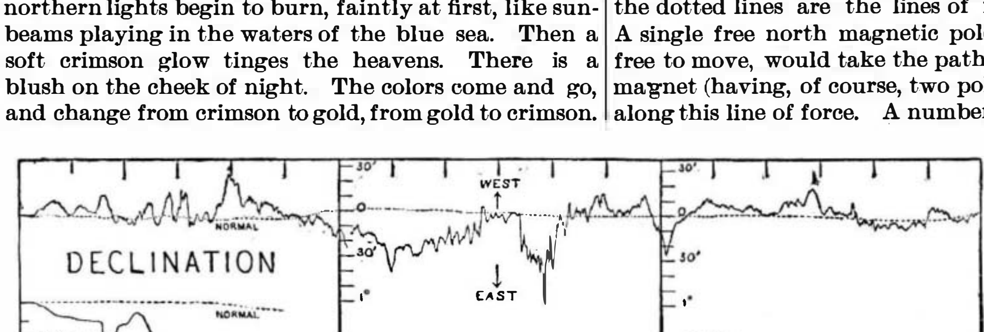

Fig. 4.—RECORD OF MAGNETIC STORM OF FEBRUARY 13-14, 1892.

(Taken at the U. S. Naval Observatory.)

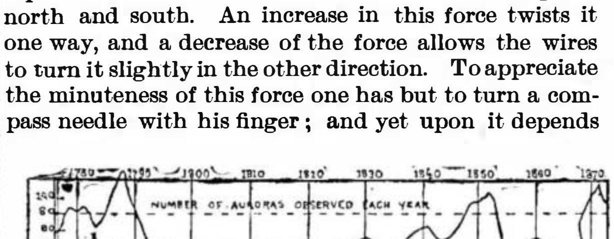

Fig. 5.—DIAGRAM SHOWING RELATION BETWEEN NUMBER OF AURORÆ, SUN SPOTS, AND MAGNETIC STORMS. (From Loomis' Chart.)

the action of the compasses which have served for centuries to guide men over the trackless waters of the globe. The third magnet rests on a knife edge at its center, with a sufficient weight on its south end to keep it nearly horizontal. An increase in that part of the earth's force which acts vertically pulls the north end down a little, while a decrease in it allows the weight to force the other end down, just as though the magnet were the arms of a balance with varying weights put in the pans at either end. The three magnets being properly adjusted, from the records made by them the direction and total magnetic force of the earth at Washington can be found for any moment.

There are three principal changes which the earth's magnetic force at any place undergoes :

1. The direction in which it acts changes slowly from year to year, making a regular swing back and forth which it takes centuries to complete.

2. It has a regular daily variation which, though small, is perfectly well defined and capable of measurement.

3. There are intervals of time extending from a few minutes to several days during which its direction and force vary rapidly, attaining an amplitude much greater than during its daily or yearly changes. These variations are called magnetic storms.

The records of an unusually severe storm of this kind which occurred on February 13 are shown in the illustration, Fig. 4, which is an exact reduced copy of the photographic traces made by the magnets at the Naval Observatory. The upper line is the declination record, and shows the direction taken during the storm by the north end of the magnet, which is free to swing round in a horizontal plane. The lower line is the record of the magnet hung by two wires. It shows the change in the force exerted by the earth to make a compass or other horizontal magnetic needle point north and south. The break in the line near noon of the 13th is due to the disturbance having become so violent that the paper was not wide enough to show it. The middle line at the left is the record of the balanced magnet, and shows the changes in the earth's vertical magnetic force. This magnet was balanced so delicately that the unusual change in the force threw it completely from its balance at 8 A. M. of the 13th. The three broken lines are records made by the same magnets on an average day, and were taken on January 1 and 2 of this year. The record shows that the storm commenced suddenly, at 12:40 A. M., February 13, with a movement of the north end of the compass needle to the westward, accompanied by a rapid increase in the horizontal and decrease in the vertical magnetic force of the earth. The declination needle remained to the westward of its usual position until 10:30 A. M., when it crossed to the eastward, remaining there until 8 P. M., after which it kept oscillating about equally on each side of its normal position. The horizontal force, after its rapid increase, decreased by a series of oscillations (apparently endeavoring to stop at its normal strength) until about noon of the 13th, when it began to increase again in the same manner, attaining a maximum at 4:20 P. M. After very violent oscillations at about its mean value, it decreased at 8:20, keeping below its normal strength during the remainder of the storm. The vertical force continued its decrease until the balance of the needle was destroyed and farther record of it lost. The occurrence of the evening aurora, at 7:30 P. M., was marked by particularly violent and sudden oscillations of the magnets.

THE CONNECTION BETWEEN MAGNETIC STORMS AND OTHER PHENOMENA.

In 1857 attention was drawn to the fact that an increase in the frequency and violence of magnetic storms occurred at times when there were unusually large numbers of sunspots, and that the appearance of auroræ in great numbers was coincident with this increase. It is now apparent that these three phenomena increase in frequency and magnitude in cycles of about 11 years, and that the maxima and minima attained by each occur in the same years. This is illustrated by the diagram, which shows graphically the comparative number of auroræ, the amount of the daily change of direction of the magnetic declination, and the relative extent of solar spots for more than a hundred years. The similarity of the curves is too marked to be merely a coincidence, and discrepancies may be easily accounted for by the incompleteness, until late years, of the records of these phenomena. That the coincidence is not accidental has also been shown by numerous occurrences, one of which, witnessed by two well known astronomers, has become classic in the literature of the sun. On the 1st of September, 1859, there suddenly appeared within the area of a large group of spots two patches of intense white light which moved rapidly across the sun's disk. They faded away as suddenly as they had appeared, but, during their brief existence of five minutes, they had moved a distance of 35,000 miles. At the same instant the photographic instruments at Kew registered a marked disturbance of the magnetic elements. This event was preceded and followed by a magnetic storm of unusual intensity over the whole earth. Telegraphic communication was interrupted, magnetic instruments showed great oscillations, and magnificent auroræ were visible in both hemispheres, even at places near the equator where such phenomena are very rare. During 1882, a year of sunspot maximum, four similar occurrences were recorded, which, though differing in detail, were equally convincing.

Professor Young has observed similar effects in connection with solar prominences which were found to be accompanied by practically instantaneous disturbances of magnetic instruments and followed by fine auroræ.

What may be the nature of the connection between these phenomena is still a mystery, but it is probable that it will be found that they depend upon some common cause, which, originating in the sun, the source of all our energy, makes itself felt on the earth, through a distance of 92,000,000 miles, by means of vibrations in the ether which fills all space.

The enormous energy which can cause vast convulsions in the photosphere of the sun, and be transmitted through such a distance, is almost appalling, and yet what knowledge we can hope to get of it is through observations made with some of the most delicate instruments known to science.

Practical Notes on Lubricants.

The laws regulating lubrication, the action which the various articles used as lubricants have upon metals, and the chemical changes that are brought about by differences of temperature, have never received the consideration due them. Of late years, however, they have been treated more seriously by owners of machinery, and a writer in the *Boston Journal of Commerce* has compiled from various sources facts which users of machinery and engineers will find useful.

Competition among manufacturers to-day demands that the utmost caution be taken to reduce the wear and tear on the machinery, to avoid loss of time, and above all, to save fuel. In almost every case the correct use of proper oil will be found the precaution necessary.

A lubricant may apparently do good work and keep the part cool, but in reality the acid formed by the friction and heat of the journals is daily damaging the surface of the metal and will ultimately do great damage.

Consumers have for years been accustomed to rely upon the salesman, whose knowledge of the goods he sells is usually found to be very deficient. Nor can every engineer's report on an oil be relied upon ; many are really ignorant, while others are personally interested.

"Some months ago I engaged a salesman," says a writer in the *American Engineer*, "an active and intelligent engineer who professed to know something about oils, and whose general ideas about lubrication seemed sensible. Upon canvassing a part of the district allotted to him with good success, so far as he went, the firm received a letter from him, saying : 'I used to think I knew something about oil, but have come to the conclusion that my knowledge will not extend beyond the outside of the barrel.' This is what nine-tenths of the engineers would come to if their knowledge were put to a practical test.

"A good oil should be used as sparingly as the nature of the bearings will permit. The amount of resistance (friction) generated by the bearings depends upon the number of revolutions a minute a machine is capable of making and the amount of power necessary to run it. In the use of oil, uniformity of distribution is as important as the regularity of supply. A dry spot on a bearing will at once cause heating, and if allowed to continue, cutting will be the result.

"There is no department in a factory more important than the engine room. As the diminishing of friction will naturally result in gain of power, it is to the consumer's interest to learn by careful experiment the oils that are best adapted to run his plant, and to make the necessary tests of density, fire test and viscosity. By so doing he can be certain to receive exactly what his machine requires, and run it at the lowest possible cost.

"'Poor oils,' says an eminent engine builder, 'are a prolific source of injury, and often defeat the purpose for which a machine was intended.'

"If a machine is not properly lubricated it will bind, heat, and then cut, and the percentage of work added to the already overtaxed Corliss is sure to injure the engine, and certainly needs an extra dip now and then into the coal pile.

"No oil has been made that can economically lubricate all the journals of a mill. An oil running a heavy engine would not do to run a spindle or a fast-revolving dynamo. The former runs slowly and has great pressure and strain on its journals, and consequently requires an oil that will not spread too quickly, but with low gravity and high viscosity. The latter needs a pure mineral oil, viscous and quick-spreading, to enable it to enter into the closest parts of the bearing as rapidly as the speed at which it revolves necessitates.

"In making an oil for a specific purpose, the speed, power, pressure upon the journals, mode of application, and temperature at which it has to run should be known. This information in hand, an oil can be made to suit.

"The numerous tests that have been made by learned men at various times within the last twenty-five years tend to show that mineral lubricants, or compounds of mineral and animal, are the safest and produce the best results.

"Professor Thurston remarks: 'Vegetable and animal oils are compounds of glycerine with fatty acids. When they become old, decomposition takes place, acid is set free, and the oils become rancid. Rancid oil will attack and injure machinery. Mineral oil does not absorb oxygen, whether alone or in contact with cotton waste, and cannot, therefore, take fire spontaneously ; animal and vegetable oils do. Mineral lubricating oils are used on all kinds of machinery; they are the safest and cheapest lubricants, and are generally superior to animal and vegetable oils and greases.'

"According to experiments by Galletry and Coleman, it was found that 'mineral lubricating oils diffused through textile cotton do not take fire even at a temperature at which colza oil ignites, and that fatty lubricants to which 20 to 50 per cent of mineral oil was added were thereby prevented from igniting.'

"Spon says: 'A mineral oil flashing below 300° is unsafe. The best oil is that which has the greatest adhesion to metallic surfaces and the least cohesion in its own particles. In this respect fine mineral oils stand first. No oil is admissible which has been purified by means of mineral acids. Mixed oil, if properly compounded, possesses the special advantages of both classes.'

"The blending of mineral and animal oils does not merely consist in shaking them together, as is supposed by many, but as they are of different gravity, the globules of each must be broken and run into each other by agitation and heat, so that the oil will become one body. If this is not done, the animal oil will become separated, and standing in a heated room, the bad qualities will become manifest, and later, when used, the oil cannot do its work, and at once the quality is condemned.

"I had a case where a large mill owner was using oil said to be one part sperm and three parts paraffine, of heavy gravity. The price was lower than I knew it could be made for. Upon analyzing a sample drawn from the barrel I found it contained 60 per cent of sperm and 40 per cent of paraffine, showing that the oil was separating. The sperm oil being lighter was coming to the top. Such oils cannot give satisfactory results.

"If you have any stipulated formula, have it made up for you by people who understand the business, and who have the facilities and appliances for doing it properly.

"Mr. Allen's experiments have shown that gumming is due to the action of free acid upon the metal bearings of machinery.

"The corrosion of bearings by oils has not received the attention it deserves, as the wear and tear of the metals and thickening of the oils has been attributed to other causes. Liquid oils corrode metals very evenly, so that the effect is not readily observed. Mineral oils contain no acid, unless they have been carelessly refined.

"I. J. Redwood says: 'Mineral lubricating oil has the least action on metals; none on iron or brass. Tallow oil has most action on iron; castor, olive and lard oils have most action on brass. Rapeseed has most action on copper.'"

The Land and Water of the Globe.

Mr. John Murray, a member of the Challenger expedition, and one of the highest living authorities on oceanography, has recently been delivering some lectures in Boston of peculiar interest to scientific men and students. Among many special papers of great value which have been published by Mr. Murray is one relating to "The Height of the Land and the Depth of the Ocean." In this learned monograph it is estimated that the area of the dry land of the globe is 55,000,000 square miles and the area of the ocean 137,200,000 square miles. He estimates the volume of the dry land above the level of the sea at 23,450,000 cubic miles and the volume of the waters of the ocean at 323,800,000 cubic miles. He fixes the mean height of the land above the sea at 2,250 feet and the mean depth of the whole ocean at 12,480 feet. Of course these results are only approximate, but they help to render our ideas of these matters more definite.

In his paper Mr. Murray also estimates that the rivers of the world carry into the ocean every year 2⅛ cubic miles of sediment. To this must be added the matter carried to the sea in solution, which is estimated at 1·183 miles of matter. Together, then, the amount of matter carried through the land each year is 3·7 cubic miles. It would thus, according to this calculation, take 6,340,000 years to transport the whole of the solid land down to the sea.

THE average daily earning of an American locomotive is about $100.