

second, silicate of alumina. The free silica gives grain, refractoriness, porosity, and low shrinkage to the sand, while the silicate of alumina furnishes bond. Free silica would be useless without the silicate of alumina, as it would not hold together. Silicate of alumina would be worthless without free silica, as it would not have sufficient porosity and would have too great a shrinkage. A confusion exists in the use of the word "silica" in respect to sand, which I shall endeavor to avoid by designating the silica existing in the free state—quartz silica.

There are several other substances present in all sand. These impurities are not at all desirable and are present from necessity rather than from choice. Quartz silica and clay in correct proportions can constitute a good molding sand without the presence of any other substance.

We will consider the individual characteristics of the constituents which make up a molding sand, for the correct combination of these properties determines the quality and grade of the sand. A knowledge of the effect of the impurities allows us to determine to what extent they may be present in a given sand and still do no harm.

#### INGREDIENTS OF MOLDING SAND.

Quartz silica, clay, iron oxide, lime and feldspar are the principal ingredients of molding sand.

**Quartz Silica.**—Pure quartz, or silicon dioxide, consists of 46.67 per cent silicon and 53.33 per cent oxygen. It is very hard, fuses at a high temperature, has no cleavage, and when pure is white. It is, however, generally colored by some oxide of iron. Its fusibility is affected by the amount of impurities present. Quartz is the chief non-shrinkage element in molding sand. It has, however, no bonding properties. The shape of its particles affects the strength of the sand, but they have no strength in themselves, as quartz is absolutely non-plastic. The size of the quartz grains determines the grade of the sand. The percentage best suited for a sand can only be determined by the kind of work for which it is used. The quartz silica should be kept as high as possible, on account of its heat resisting power, its tendency toward porosity and its low shrinkage.

**Bond or Clay.**—The bond of a molding sand is a clay product. Pure clay or kaolinite is a hydrated silicate of alumina—that is, a silicate of alumina containing water of combination. The exact composition of pure clay is silicon dioxide, or silica, 46.4 per cent; alumina, 39.7 per cent.; water, 13.9 per cent. It is this 13.9 per cent. of combined water which gives the plastic properties to the clay. The bond of a molding sand is not pure clay, but is generally mixed with impurities which weaken its binding power. Clay is formed by the decomposition of feldspars. These are rocks containing silicate of alumina together with silicates of the alkalis. The clay acts as a binder for the sand and holds the refractory quartz silica together. The purity and plasticity of the clay determine the amount necessary to give a sand its correct bonding strength. The clay when pure is very refractory, and it is fallacy to think that because there is a large proportion of bond in a sand it is low in refractory qualities. A high percentage of clay in a sand destroys its porosity and causes high shrinkage and consequently cracks. A sand should be chosen with as low a clay content as is consistent with shop conditions. In foundries where a large percentage of old sand is used it is absolutely necessary to use a new sand containing a high percentage of bond. This is not conducive to the best results. There are, however, certain classes of work the appearance of which must be sacrificed to cheapness of material, and such conditions require that a large amount of old sand be used in the facings. When a lower proportion of old sand is used a new sand with less bond and consequently higher quartz silica will give a more porous facing.

**Feldspar.**—Feldspars are silicates of alumina combined with silicates of the alkalis. These are generally present in small amounts in molding sand, but they should be kept as low as possible, on account of their fusibility, as they tend to flux the rest of the sand and bind it together.

**Oxide of Iron.**—Oxide of iron is present in all molding sand, giving it its reddish color. It may be united with the bond as an impurity, or it may form a part of the quartz silica. In either case it lowers the fusing point. The iron comes into the sand either from the original rocks from which the sand was formed or from water containing iron which has trickled through the sand.

**Lime.**—Lime is sometimes present in molding sand. It makes the sand fusible and liable to crack and crumble in the mold. It may come from the water which has aided in the decomposition of the rocks during the formation of the sand.

#### ANALYSIS OF MOLDING SAND.

The ultimate analysis of a good molding sand will give results within the following limits:

	Per cent.
Total silica .....	75 to 85
Alumina .....	7 to 10
Lime, below .....	2
Alkalies, below .....	0.5
Oxide of iron, below .....	6

The total percentage of iron oxide, lime, and alkalies or the total fluxing agencies should not ordinarily exceed 7 per cent in one sample. In a high grade molding sand used for heavy work they should not exceed 5 to 6 per cent.

A sand analyzed by the rational method should give

a quartz silica of from 60 to 70 per cent, a clay substance of from 20 to 30 per cent, with a feldspar below 10 per cent. If the iron were determined separately and subtracted from the clay substance with which it is included by this method we should have a fair indication of the properties of a molding sand, as far as its refractoriness is concerned. The strength is so dependent upon the purity and condition of the clay that it cannot be accurately gaged by any analysis.

Two molding sands, one a so-called strong sand and the other a rather sharp sand, both of which would be classed as a No. 4, give the following results by ultimate and rational analysis:

#### Sharp Molding Sand.

##### Ultimate analysis.

	Per cent.
Silica .....	86.66
Alumina .....	9.30
Iron oxide.....	4.53

##### Rational analysis.

	Per cent.
Quartz silica.....	67.85
Clay { including iron oxide.....	22.03
substance { excluding iron oxide.....	17.50
Feldspar .....	10.12

#### Strong Molding Sand.

##### Ultimate analysis.

	Per cent.
Silica .....	77.22
Alumina .....	9.26
Iron oxide .....	5.56

##### Rational analysis.

	Per cent.
Quartz silica.....	64.66
Clay { including iron oxide.....	28.06
substance { excluding iron oxide.....	24.50
Feldspar .....	7.28

#### REFRACTORINESS.

The impurities which impregnate a molding sand greatly reduce its refractoriness. The sodium and potassium salts in the form of feldspars and mica are constituents of all clays to a greater or less extent and consequently form a part of all molding sands. These alkalies, fusing at a low temperature, may bind the rest of the substances into a hard mass. Iron oxide also increases the fusibility, as does lime, which is occasionally present. This latter is most harmful when present as a carbonate, as a gas would be given off at a high heat which would prove detrimental to the mold. The size of the grain of a sand may affect its refractoriness. Several experts on clays have demonstrated that under certain conditions the fusing point of the clay is determined by the size of the grain. It is probable that this holds good in regard to a molding sand, the larger grained sand having a higher fusing point.

#### POROSITY.

Some sands are naturally porous, while others are very impervious to gas and moisture. The porosity of a sand determines the amount of venting necessary. Some sands must be vented very freely for all grades of work, while with others the use of a vent rod is hardly necessary. There are four factors which determine porosity: First, the proportion of quartz silica to the bond; second, the size of the quartz silica particles; third, the shape of the quartz silica particles; fourth, the condition of the bond. Generally speaking, the higher the proportion of the quartz silica the greater will be the porosity of the sand. The larger the quartz particles the more porous will the sand be. It will be apparent, however, that the size is limited, from the fact that a sand cannot be too coarse and still give a finish to the casting. The particles should therefore be kept as large as possible and still produce the desired effect as to finish. The porosity is also affected by the shape of the quartz silica particles. Irregular crystalline structures with sharp edges and corners will leave greater spaces between the particles than will regular shaped particles with smooth surfaces, which are apt to fit closely together and thus prevent a free passage of gas or air. The less the proportion of bond used, and still have sufficient binding power in the sand, the greater will be the porosity. It follows therefore that the stronger the bond the less the quantity necessary to produce the same results, consequently the sand having the strongest bond requires the lowest percentage of bond. The tendency of clay to bake together and destroy the porosity of the sand and its tendency to crack, due to excessive shrinkage when drying, render the presence of a large amount of clay bond objectionable. It is very necessary that a sand be chosen with a low percentage of strong bond rather than a large percentage of weak bond.

#### STRENGTH.

The strength of a molding sand determines its adaptability for different kinds of work. Some castings may be made with sand having comparatively little strength, while for others a strong sand is absolutely necessary. The amount of strength necessary is somewhat dependent upon shop practice. The methods of molding, running, venting, and mixing of the sand must all be considered in determining the proper strength of a sand for a given class of work. The practice of using flour, molasses or clay wash in mixing up facing, together with the proportion of coal dust and old sand used, is also an important factor to be considered in the choice of a sand. In foundries where nailing is generally resorted to, a weaker sand may be used than where nails are not used. A good mechanical mixer which intimately surrounds each

particle of old sand with particles of new sand, rather than putting the old and new sand together in chunks, also permits the use of a sharper sand. Where flour or molasses is used or where the proportion of old sand to new sand is comparatively small, the use of a sharp sand is possible.

The strength of a sand depends upon three conditions: First, the proportion of bond; second, the strength of the bond, and, third, the shape of the quartz silica particles.

#### SIZE OF GRAIN.

The grade of a molding sand is determined by its grain. The finer grained sands are used for the lighter work. Sands are graded and sold by numbers, based upon the size of the grain.

A sand should be as fine grained as possible and still satisfactorily fill the other requirements of a molding sand. This is due to the fact that the finer grained sand will give a better surface to the casting. The grain of the sand is determined largely by the grain of the original rock from which the sand was formed. The fineness of the sand is obtained quantitatively by the use of a series of sieves. Of these, 100, 80, 60, 40 and 20 mesh are used. A weighed amount of the dried sand is placed in the 100-mesh sieve, which is shaken for a definite time, say, one minute. The siftings are carefully weighed and the weight recorded. The 80, 60, 40 and 20 mesh sieves are used in the same way. These separate weighings are multiplied by the number of the mesh of the sieve. There is a certain loss due to dust flying, etc., which is found by subtracting the total of the weights obtained from the original weight. This loss is multiplied by the average mesh of the sieves, which is 60. The sum of the products of the weights obtained by the number of the sieves divided by 100 constitutes what is known as the degree of fineness of the sand. This method is quite unsatisfactory in many ways, as all sands of the same degree of fineness do not have the same physical effects when used as a molding sand. This is due to the fact that the proportion of sand which passes through each sieve has an important bearing upon the quality of the sand. A sand whose particles are all small but of uniform size will give better results than one with a combination of large and small grains which might be of the same degree of fineness when judged by the standard sieves.

It is never advisable to judge of the fineness of a sand by its appearance, for a comparatively few large particles will give the whole sand the appearance of being coarse, while in reality it may be very fine when judged by the standard sieves.

#### CONCLUSION.

We have looked at molding sand from two viewpoints: First, as a study of the materials which go to make up a molding sand, and, second, as a study of the properties which are necessary and most desirable in a molding sand. A thorough understanding of the principles considered should aid us in intelligently selecting the best sand for our individual use.

Let me remind you that what proves to be a good sand in one foundry may prove just the opposite under the differing conditions of another. It is with this fact strongly in mind that I give you general information rather than specific data which might apply to one set of conditions. Any future improvement in the quality of molding sand will come from an intelligent interpretation of the principles which we have studied to-night.

[Continued from SUPPLEMENT No. 1581, page 25334.]

#### LIGHTNING AND THE ELECTRICITY OF THE AIR.—II.\*

By ALEXANDER G. MCADIE.

#### SOME MEASUREMENTS OF THE POTENTIAL OF THE AIR.

**EXPERIMENTS at the Smithsonian Institution.**—In 1886 some investigations on atmospheric potential were undertaken at Washington, under the direction of General Hazen, Chief Signal Officer, and more immediately under the supervision of Prof. Mendenhall. Experiments were made by the writer at the tower of the Smithsonian Institution. The electrical history of a summer afternoon thunderstorm may be read in the following record of the potential changes. June 14, 1886; a showery and oppressive morning; the wind very light and coming in feeble puffs; southwest at 11:30 A. M. (See next page.)

Experiments at the Top of the Washington Monument.—The electrical history of a thunder storm as indicated by an electrometer at the top of the monument is very interesting. The following is a description of one of many experiments thus made:

May 6, 1887. We are 500 feet above the city streets. It is a warm afternoon and looking from the west windows of the monument one sees through the near haze around Arlington and Virginia hills far to the southwest a patch of dark cloud. It needs little experience to presage a thunder squall. It is about twenty miles away and will reach us in about forty minutes, perhaps in less time. At ten minutes to three o'clock the clouds are overhead, and this is the last we shall see of the world outside until the storm is over, for it is necessary that the heavy marble doors be swung to. All is dark in the monument save for the beam of reflected light traveling along the ground glass scale. The little mirror reflecting the light is attached to the electrometer needle, and in this way the most minute movement of the needle is made known. From the south window the nozzle of

\* Reprinted from Journal of Electricity, Power and Gas.

the water-dropping collector protrudes through a small opening. The wind rises, and we notice the needle moving steadily toward the point marked 1,000 volts, positive. This means that the pull upon the air is steadily increasing. Suddenly the needle flies to the other side of the scale and we know that the air, like a piece of over-stretched rubber, has snapped and given way under the strain. The pull is now negative, i. e., in an opposite direction, and now the needle dances and we hear outside the rumble of distant thunder, all indicating the approach of the disturbance. Nearer comes the storm, if we may judge from the rapid fluctuations of the needle. Values of 3,000 and 4,000 volts are common.\* The deflections are at times greater than the scale limits. With every flash of lightning we catch the fleeting reflection of a little spark in the electrometer. On one occasion running a wire from the ironwork to within a small distance of the collector we counted more than 100 1/8-inch sparks in a minute. If we place the eye close, but not too close, to the little peep-hole through which the nozzle goes, we shall see the stream of water twisting and breaking into spray, and each time it lightens, becoming normal quick as the flash itself, but only to rapidly twist and again distort itself.

Increase of Potential with Elevation.—Some idea of the normal rate of increase of potential with elevation can be gained from the following table:

TIME, A DAY IN NOVEMBER. THE TWO STATIONS ABOUT 500 FEET AND 45 FEET, RESPECTIVELY.			
Time.	Monument.	Signal Office.	Difference.
P. M.	Volts.	Volts.	Volts.
1:30	900	216	684
1:32	888	246	642
1:34	900	216	684
1:36	862	246	616
1:38	875	240	635
1:40	825	222	603

THE ELECTRICITY OF THE UPPER AIR AS MANIFESTED IN AURORAL DISPLAYS.

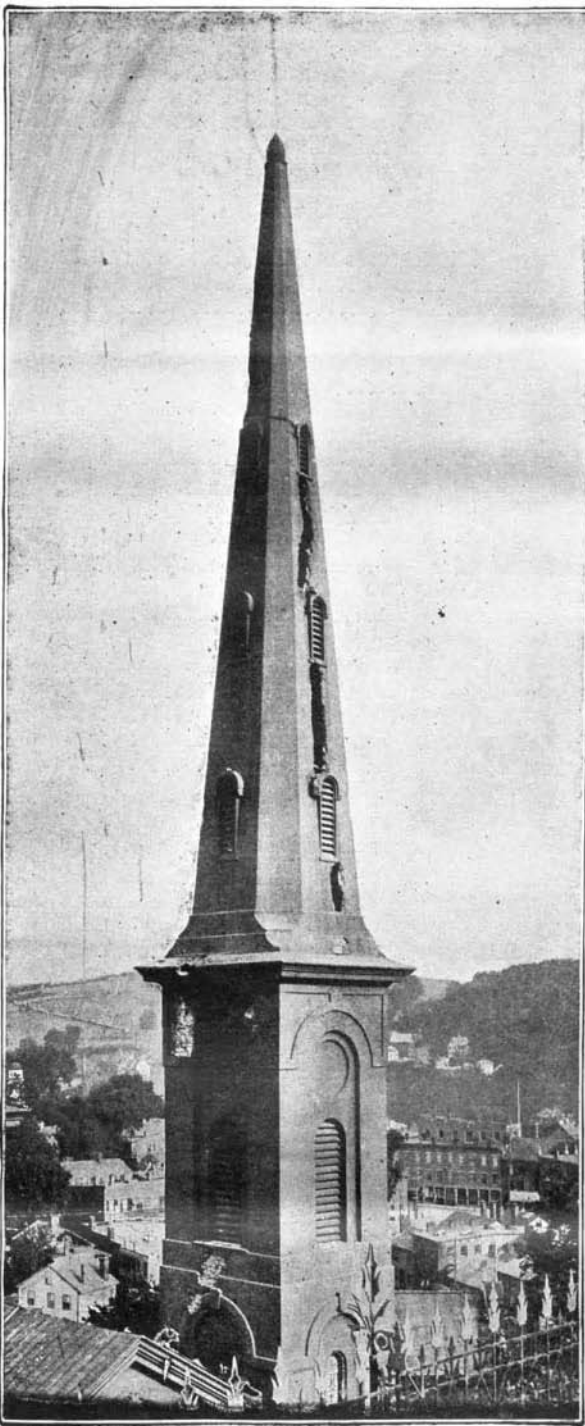
One of the great mysteries of the upper air is the aurora. No paper treating of the electrification of the atmosphere can be complete without a more or less imperfect knowledge of this most beautiful of all electric displays. The following brief review is from an article published in the Century Magazine for October, 1897, somewhat modified to suit the requirements of the present publication:

WHAT IS AN AURORA?

On the first day of January, 1892, Dr. Brendel and Herr Raschen reached the Alton Fiord, Lapland, to remain several months, studying the auroral displays and magnetic disturbances. Brendel succeeded in photographing the aurora, a very difficult thing to do, as all who have attempted it know. The deep reds, which are so beautiful to the eye, make little impression on the photographer's plate, and the light itself is generally feeble and flickering. Not unaptly have the quivering auroral beams been called "merry dancers." Even the bright displays are hard to photograph, as we may see from an entry in Gen. Greely's notebook on January 21, 1882: "A most beautiful aurora," he says, "with intense light, at times sufficiently bright to cast my shadow on the snow. Rice exposed a sensitive plate without effect, but the constantly-changing position of the aurora may have been the cause." Once the sun-spot period was clearly established, it was only necessary to ransack chronological lists of auroras to find how intimately auroras and sun spots were connected. Three patient investigators, Wolf, Fritz, and Loomis, soon proved that auroras were most frequent when sun spots were most numerous.

\* At the Eiffel Tower values as high as 10,000 volts have been obtained.

The next step was to find individual relations. One bright September morning thirty-seven years ago, Carrington and Hodgson, separately studying the face of the sun, saw a remarkable outburst near the edge of a great spot. For some days the magnetometers at



PHOTOGRAPH OF BROADWAY CHURCH,\* NORWICH, CONN., DAMAGED BY LIGHTNING JULY 29, 1894, 1:30 P. M.

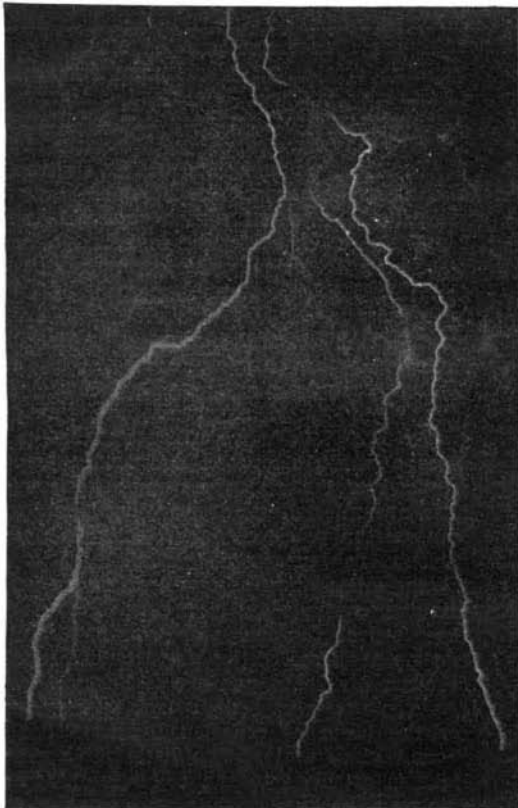
Photographed by Mr. F. J. Moulton.

Kew showed unusual perturbation, and for several nights magnificent auroral displays were seen over

\* The spire is of brick, 198 feet high, with a cap of brownstone. It was not protected by a lightning rod. See SCIENTIFIC AMERICAN, September 8, 1894.

Time.	Volts.		Remarks.
	+	-	
11:30 A. M.	78	.....	Wind southwest, light.
35	54	.....	
40	60	.....	
45	36	.....	
50	54	.....	
55	54	.....	Wind from south-by-east, puffs, no particular cloud conditions.
58	78	.....	
12:40 P. M.	66	.....	
45	72	.....	
50	3	.....	
52	.....	66	Very light rain began at 1:02 P. M.
55	.....	138	
57	.....	168	
1:00	.....	210	
02	.....	90	
08	.....	42	Distant thunder at 1:09. Clouds in west looking like advance guard of thunder-storm, with some blue sky, however.
05	.....	120	
07	.....	193	
09	.....	216	
10	.....	210	
11	.....	198	Thunder at 1:13:25. Clouds also in north-west. Thunder from 1:16:20 to 1:17:40. Rain commenced at 1:17; lasted five seconds.
12	.....	186	
13	.....	156	
14	.....	132	
15	.....	108	
16	.....	108	Rain commenced 1:20:15; light. Ended 1:22. Thunder at 1:22:20.
17	.....	96	
18	.....	96	
19	.....	78	
20	.....	72	
21	.....	54	Very light rain commenced 1:27:30.
21-22	54-72	.....	
22	.....	54	
23	.....	30	
24	.....	30	
25	.....	30	Very distant thunder.
26	.....	12	
27	.....	6	
28	.....	12	
29	.....	54	
30	.....	78	Light rain. Rain ended 1:39:20.
32	.....	192	
33	.....	246	
34	.....	240	
35	.....	252	
38	.....	234	Rain commenced 2:01 P. M.
39	.....	180	
40	.....	174	
1:43 P. M.	.....	150	
44	.....	120	
45	.....	72	A very heavy cumulus cloud is moving up toward the place of observation from the river.
48	.....	24	
50	.....	12	
55	.....	66	
58	.....	78	
2:00	.....	78	Bright and shining; large, white cumulus clouds in southwest, southeast and east, but the northwestern horizon is black and evidently a storm is coming.
01	.....	78	
05	.....	78	
09	.....	90	
10	.....	90	
13	.....	72	First thunder 3:03:15 to 3:03:40; thunder 3:07:30 to 3:07:42; calm; thunder 3:09:10 to 3:09:13.
15	.....	84	
17	.....	96	
20	.....	90	
21	.....	66	
23	.....	72	Thunder 3:10:08 to 3:10:10.
25	.....	66	
30	.....	48	
35	.....	48	
40	.....	54	
45	.....	30	Thunder 3:12:25 to 3:12:27.
50	.....	30	
55	.....	24	
57	.....	0.0	
58	.....	12.0	
3:00	.....	114.00	Thunder 3:15:30 to 3:15:32.
02	.....	150	
03	.....	186	
04	.....	228	
05	.....	276	
06	.....	300	Thunder 3:17:30.
07	.....	312	
08	.....	.....	
09	.....	348	
10	.....	360	
11	.....	390	Thunder 3:18:30 to 3:18:32.
12	.....	396	
13	.....	420	
14	.....	444	
15	.....	438	
16	.....	444	Thunder 3:17:30.
18	.....	480	
	.....	504	

two continents. It was long thought that a violent magnetic disturbance occurred *simultaneously* with the outburst, but recent examination of the records disproves this. In 1872 Prof. Young noticed a disturbance in the chromosphere in the neighborhood of



MULTIPLE FLASH.

From Popular Science Monthly, 1898, McAdie.



DESTRUCTIVE FLASH.

From photograph by McAdie.



CLOUD AND MULTIPLE FLASH.

From photograph by McAdie.



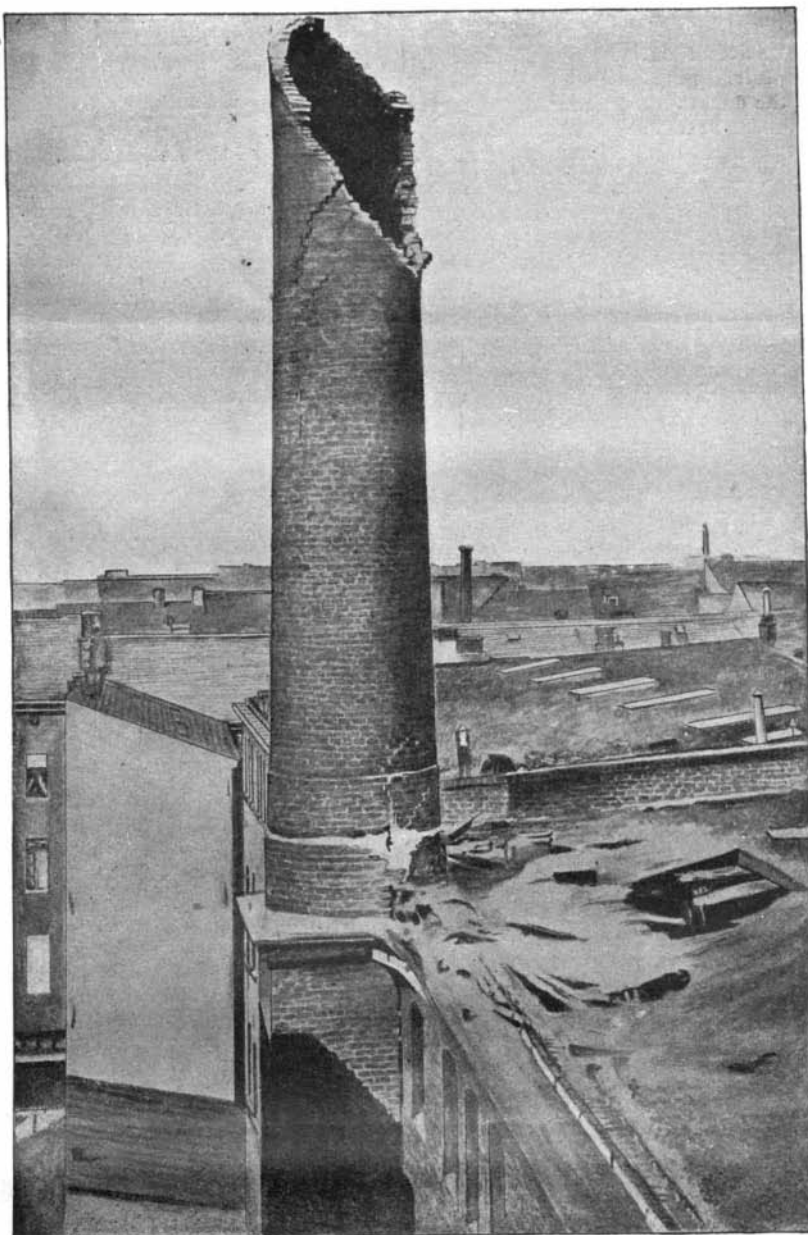
a sun spot, and upon asking the astronomers at Greenwich and Stonyhurst to examine their magnetic records, it was found that great disturbances had occurred about that time. Ten years later the astronomer at Greenwich sent out a message that read something like this: "Remarkable sun spot now visible. . . . Area of whole spot, 247/100,000 of the sun's visible surface." Try to imagine what this means, and fancy yourself on the sun while that tremendous storm was in progress. We know that here on earth there was a magnetic storm with auroral displays that beggars description. Beginning a little before daylight on November 17, 1882, not a wire of the Western Union Telegraph Company could be used for three hours. The market quotations could not be sent. Late in the afternoon the trouble seemed to decrease, but at night there was a brilliant auroral display, and all telegraphic service was again interrupted. A very short circuit from Boston to Dedham showed the disturbance equally with other circuits. The cables to Europe and the wires to Chicago were alike unworkable. A message was sent from Bangor to North Sydney, 700 miles, by cutting out the regular batteries and allowing the energy of nature to have its own way. The current was just as strong as if a hundred cells had been at work. At Albany the switchboard was ignited; and in telephone offices generally the annunciators dropped continually. Switchboards and wires were burned at Chicago. Incandescent lamps were illuminated in St. Paul, and even in far San Francisco the telephone operators were nigh distracted. Over half of North America, across the Atlantic, and on over northern Europe it seemed as if legions of ethereal demons were busy inciting electric and magnetic apparatus to strange and mischievous antics.

It so happened that about the pole that year were clustered representatives from twelve nations. The Russian international expeditions were at the Lena Delta and Nova Zembla; the Norwegian at Bossekop; the Dutch at Dicksonhavn; the German at Kingua Fiord; the Finnish at Sodankyla; the Swedish at Spitzbergen; the Danish at Godthaab; the Austro-Hungarian at Jan Mayen; and the British at Fort Lee. France had two stations in the Antarctic region, and our own country had the well-known Lady Franklin Bay party under Greely, and the Point Barrow party under Ray.

November 14-19, 1882, was a period never to be forgotten by these Arctic prisoners. While we at home saw the display of a decade, the observers of the frozen North, turning their eyes southward or westward or eastward, saw visions glorious by day as well as by night, and felt perhaps some measure of recompense for their isolation and peril. Coming out of their dark quarters, they were startled and at first blinded, and Gen. Greely writes: "The curtain appeared at one time so near our heads that Gardner and Israel speak of having unconsciously dodged to avoid it." In Ralston's diary is the entry: "The aurora appeared so low down that I raised my hand instinctively, expecting to bathe it in the light"; and Brainard relates a like impression. What a pity that under such conditions no electrometric apparatus was available! With Thomson water-dropping collectors and multiple-quadrant electrometers, records of the electrification of the lower air could have been obtained, and a few more threads raveled out from nature's tangled skein. Some observations of the potential of the air, made by Andree, who was a member of the Swedish party at Cape Thorsden, Spitzbergen, seem to show that the electrical potential diminished very rapidly during an aurora, and in fact became negative. As is well known, this same Andree has lately attempted to reach the pole in an airship. Not the least valuable

result of the adventure will be the increase in our knowledge of the electricity of the air in polar regions. We shall learn a little more about the height of auroras. We know now that while they are from fifty to seventy miles high in latitude 50 deg., the height decreases as we approach 68 deg. At Godthaab, Paulsen measured many with theodolites, and found that

Our little planet unquestionably responds to solar disturbances. The intense auroral displays that occur simultaneously over continents are, one may think, answering signals to the messages flashed from the sun through the quivering ether. But we may also have our own little storms and disturbances; and while appearances may be similar, the phenomena are

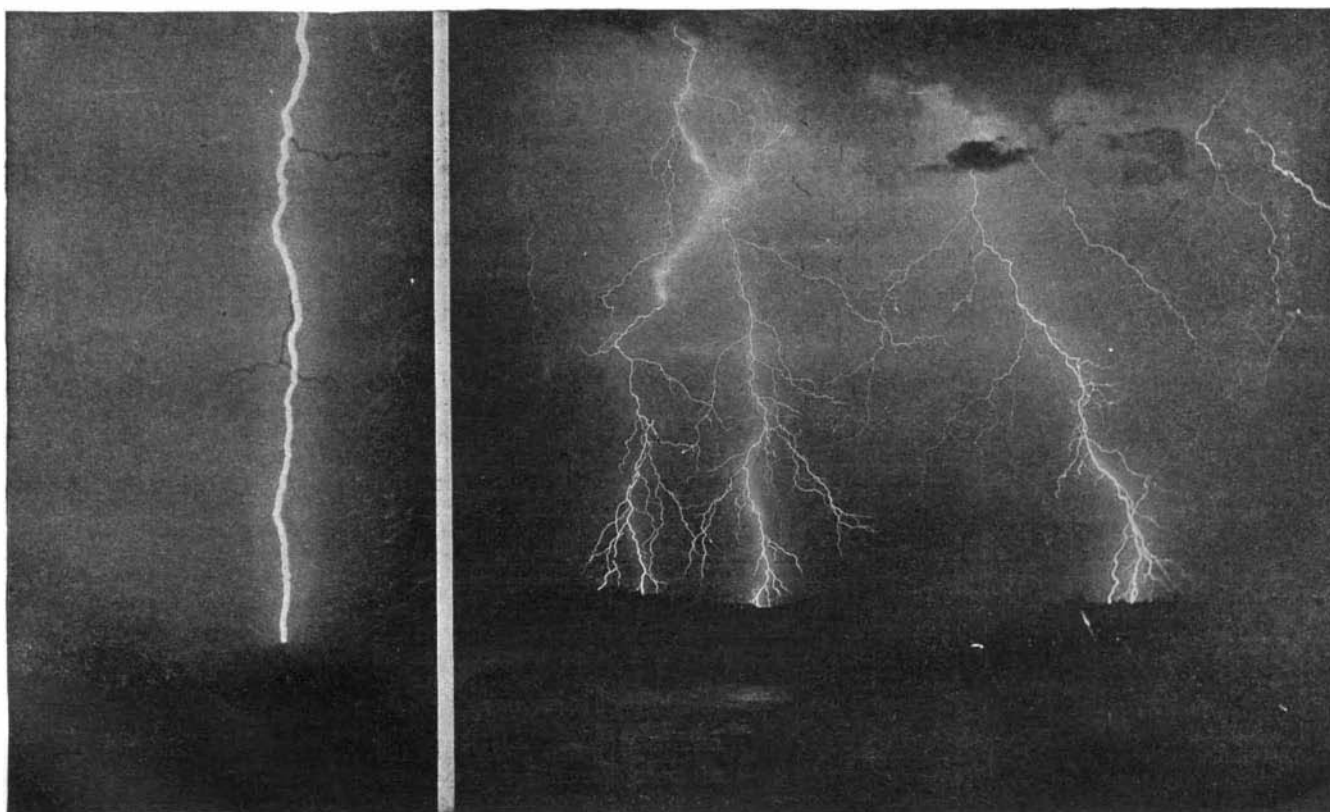


CHIMNEY, STRUCK JULY 29, 1890.

From Elec. Zelts., Greibel.

some were less than two-fifths of a mile high. Hildebrandsson and others have seen auroras below the clouds. Such results lead us to believe that the time is ripe to suggest a new classification of auroral displays. It has been further noticed that the colorless and quiescent auroras were not necessarily coincident with magnetic disturbances, while those of brilliant color and rapid change were. Many so-called auroras are probably what the Germans would call *Wetterleuchten*, and akin to silent lightning.

of different origin. Some of the difficulties and discrepancies which have been met in tabulating sunspot, magnetic, and auroral phenomena can be thus explained. One wise remark by Prof. Young should not pass unnoticed. "The solar tumult," he says, "may be the brother, and not the father, of our aurora." But this much is plain: The phenomena are closely allied, and mastery of the terrestrial displays will enable us to reach out and attempt the conquest of the solar ones. It may be frankly said that the man of



IMPULSIVE RUSH AND SO-CALLED DARK FLASHES.

From Popular Science Monthly, McAdie.

MULTIPLE FLASH.

From Scribner's Magazine, A. Binden.

science feels that the aurora has baffled his scrutiny.

#### PROTECTION FROM LIGHTNING.\*

At the Aberdeen meeting of the British Association for the Advancement of Science, Sir William Thomson made the remark, "If I urge Glasgow manufacturers to put up lightning rods, they say it is cheaper to insure than to do so."

This was the answer given by practical business men, concerned only with questions of profit and loss, to the foremost physicist of our time; and their answer will serve as fairly representing views widely held, founded upon the double belief that the risk from lightning is not so very great and the protection afforded by the present methods not sufficiently certain to warrant implicit confidence and justify the necessary expense.

The recent remarkable experiments of Dr. Oliver Lodge, in his lectures before the Society of Arts, opposing and to some degree directly contradicting the empirical rules of the Lightning Rod Conference, have given support to the belief that the protection was uncertain. Indeed, realizing that his work might be misinterpreted, Lodge has stated: "An idea at one time got abroad that my experiments proved existing lightning conductors to be useless or dangerous; this is an entire misrepresentation. Almost any conductor is probably better than none, but few or no conductors are absolute and complete safeguards. Certain habits of lightning rod practice may be improved and the curious freaks or vagaries of lightning strokes in protected buildings are intelligible without any blame attaching to the conductor; but this is very different from the contention that lightning rods are unneces-

into prominence, and the time is not far distant when the lightning flash will be studied as an electrical discharge of this character. Protection entirely adequate for such discharges will then be forthcoming. Indeed, the reasons why present methods occasionally fail are now understood, and the proper remedies apparent.

#### LIGHTNING CONDUCTORS.

Beyond doubt Franklin proved his case that lightning rods were efficacious in the protection of buildings. Buildings with conductors when struck by light-



Effect of the Action of Lightning Upon a Rod.

ning suffered little damage compared with those without protectors.

The chief defects likely to occur are blunted points and breaks in the continuity of the connection. The function of a lightning rod is two-fold; first, that of conducting the charge to earth, and second, the prevention of a disruptive discharge by silent neutralization of the cloud electrification. The latter explains why a rod terminates in a point, and likewise why points in good connection with the ground are always desirable upon buildings. Indeed, points are somewhat like small water pipes connected with a large reservoir. If you have enough of them and a sufficient time you may drain the largest reservoir. Furthermore, when some sudden rise or flood occurs in the reservoir, these minute drains may be of service in keeping the height of the water down.

In the case of lightning the points are the small

first know is, whether the condition is to be one of "steady strain,"\* or "impulsive rush"† discharge. In the case of "steady strain," the metal is apt to influence the path of discharge; in the case of an "impulsive rush" discharge, even points seem to lose their efficiency and become of little use.

In a letter‡ of an old British admiral there occurs a description of his being called upon to approve some specifications for a lightning conductor to be erected on a certain lighthouse. He was himself a believer in the "surface" theory of Harris; but thought that, to make sure, he would go and consult his friend Faraday. Faraday, who saw only the question of conductivity in the problem, said very positively that the solid rod was better than the tube (which gives greater surface with less copper), and that *solid volume was everything*, superficial area nothing. Moreover, if Harris says otherwise, "then he knows nothing whatever about it." The admiral straightway approved the solid rod conductor for the lighthouse. Within two or three days he met Harris, and bringing up the question was told by Harris, "Surface area is most important, and if Faraday says otherwise, then he knows nothing whatever about it."

Up to a certain point Faraday was right; a copper rod an inch thick is capable of carrying almost any flash of lightning, and is undoubtedly a great protector, but if, as we have reason to believe, the core is seldom given a chance to carry the current, why have it? The views of Sir W. Snow Harris, based as they were upon close study of many thousand cases of lightning action, are finding in the experiments of to-day the confirmation so long needed.

While not going into details regarding this question of the shape of the rod, let us emphasize the fact, so recently brought out, that if an electric current flows steadily in one direction in a cylindrical wire, as shown by Hertz, but that with a current of an oscillatory character, i. e., a current which rapidly reverses its direction, this condition no longer holds, and if the direction is altered very rapidly, the interior of the wire, in our case the lightning rod, may be almost free from current.

In 1882 appeared the report of the Lightning Rod Conference, in many respects the most important contribution to the literature of the subject yet made. While so many foreign governments, and in particular France, had by means of officially constituted boards taken a governmental interest in the protection of the people from the dangers of lightning, the English speaking people of the world, aside from the few directions officially issued for the protection of magazines and lighthouses, remained without any authoritative utterance upon the subject; and while this conference itself did not have strictly official sanction, it carries, from the character of its makeup, a weight certainly as great, if not greater, than an official board. It was simply a joint committee of representative members of the Institute of British Architects, the Physical Society, the Society of Telegraph Engineers and Electricians, the Meteorological Society, and two co-opted members. As might be anticipated from such auspices, the report is an excellent one, and must stand for years as the embodiment of the most widely gathered information and well considered decisions. The report is emphatically one based upon *experience*.

The famous free-for-all discussion which occurred at the British Association meeting in 1888, so far as our judgment goes, simply proved that the decisions of the conference could not at present be disregarded. As the president of the meeting, Sir William Thomson, said, "We have very strong reason to feel that there is a very comfortable degree of security, if not absolute safety, given to us by lightning conductors made according to the present and orthodox rules." There are one or two further features to which attention may be called. There are some very prevalent misapprehensions with regard to lightning—for example, that it never strikes twice in the same place; that the most exposed place is always struck; that a few inches of glass or a few feet of air will serve as a competent insulator to bar the progress of a flash that has forced its way through a thousand feet of air, etc. These are alluded to in the following general directions.

(To be continued.)

#### CELLULOID AND GALALITH.‡

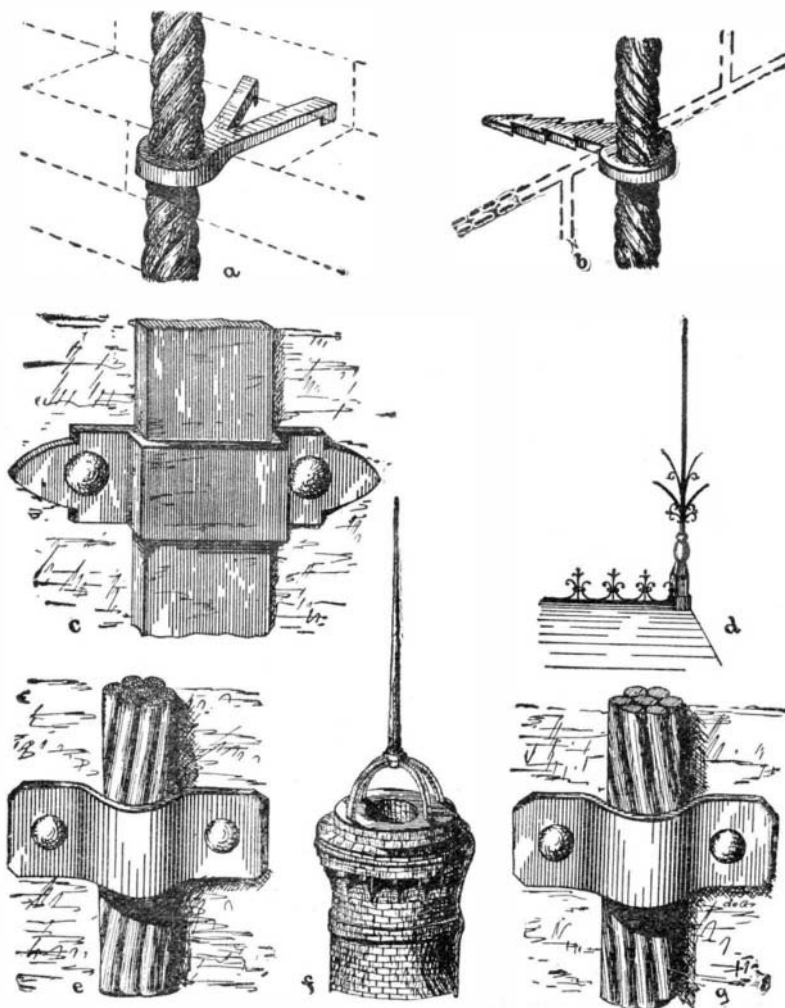
THE comparative study of both substances is interesting, both on account of the similarity of their properties and the resulting applications, and their preparation and chemical composition, which are quite different. These two organic substances, prepared artificially, are employed in the manufacture of toys and objects imitating horn, amber, ivory, coral, malachite, and ebony.

Celluloid plays an important rôle in photography, in which it has become indispensable in the form of films. This chemical product, a solution of nitrocellulose in camphor, was first prepared by the brothers Hyatt in 1869 at Newark in the United States. Galalith, more interesting since it is a newer product, made its appearance but a short time ago. The name was adopted by the manufacturers, the Vereinigte Gummiwaren-Fabriken, of Harburg and Vienna, and may be translated as "milk-stone," though the form of the word is slightly irregular and really should be "galactolith." It is derived from milk, but not as some periodicals have asserted, from petrified milk.

\* Terms used by Prof. Lodge.

† See report of Lightning Rod Conference.

‡ From the French of M. R. Coulon in the Revue de Chimie Industrielle.



CONDUCTORS AND FASTENING.

From Anderson, and Lightning Rod Conference.

sary and useless. They are essential to anything like security."†

What Lodge's brilliant experimental work does show is that the momentum of an electric current can not be overlooked in a lightning discharge. The old "drain-pipe" idea of conveying electricity gently from cloud to earth must give place to the new proposition, based upon recent discoveries, that even draining off must be done in an appropriate way to be effective. To illustrate, the rocks and trees upon a mountain side may influence and determine the course of a mountain stream, but even a good-sized channel would not suffice to carry off safely an avalanche, or control the path of a landslide; so with lightning. In the last four years we have learned, through the work of Hertz and others, that, when an electric current flows steadily in one direction in a cylindrical wire its intensity is the same in all parts of the wire; but if the current be of an oscillatory character, i. e., a current which rapidly reverses its direction, the condition no longer holds, and if the alternations are very rapid the interior of the wire may be almost free from current. If lightning then be a discharge of an oscillatory character, it may happen that the current down the lightning rod would be only *skin deep*. The experiments of Tesla and Elihu Thomson with currents of great frequency of alternation and very high potentials open the door to systematic study of discharges such as the ordinary lightning flash. In daily work currents of this type are coming more and more

escape pipes, the layer of air between cloud and earth the retaining wall, and the cloud electrification—or charge—the overflowing or destructive element. A large conductor, be it rod or tape, on the other hand, is more like a large main or waterway, which has its gate shut until the flood is imminent. Then the gate is suddenly opened and we try to compel the torrent to keep to the provided path. We trust in its ability to safely hold the flood. Generally it does. In perhaps nine cases out of ten, the lightning conductor, if it be such a one as we will describe later, does carry the flash to the earth; but there are cases where the discharges have been heavy and overflows have resulted. To carry the lightning flash "the lightning conductor should offer a line of discharge more nearly perfect and more accessible than any other offered by the materials or contents of the edifice we wish to protect." To prevent the discharge "the conductor should be surrounded by points." These quotations are from the Report of the Lightning Rod Conference.

The statement that lightning always follows the path of least resistance, as commonly understood and stated, needs modification. True it is, that when the air is strained by being subjected to the electrifications of cloud and earth, the weakest spot gives way first, and this is apt to be in line with some small elevated knob or surface; but it is equally true, and is perhaps the more general case, that when a really vigorous disruptive discharge does occur, it is somewhat, as Dr. Lodge aptly puts it, like an "avalanche." As a matter of fact, we find from the study of actual cases where buildings have been struck, that lightning often disregards metallic surfaces and points. What we should

\* From Bulletin No. 15, U. S. Weather Bureau.

† Page vi. "Lightning Conductors and Lightning Guards."