

cannot resist the temptation even if the bait is poisoned.

- (3) Kerosene oil ..... 8 ounces  
Oil of wintergreen, a sufficient number of drops.  
For bedbugs, you might modify the foregoing formula as follows:

- (4) Oil of wintergreen ..... 2 drops  
Benzine ..... 1 ounce  
Turpentine ..... 2 ounces  
Kerosene oil, enough to make ..... 8 ounces

This combination beats anything I ever heard of for bedbugs. It will kill them by contact. The oils dissolve the wax coating of the bug and penetrate to its vitals. The other preparations mentioned are good and

most of, and claim every merit for. Put it up in a bottle and sell for about 15 cents. A label bearing name and directions and your business address will be required. Give the following directions for use: "Shake the liquid into all the cracks and crevices where the bugs are likely to hide." You must not neglect to put a paper bottle-cap over the cork.—Bulletin of Pharmacy.

#### MANUFACTURE OF CEMENT FROM MARL AND CLAY.\*

By HENRY S. SPACKMAN.

The chemical elements necessary for the manufac-

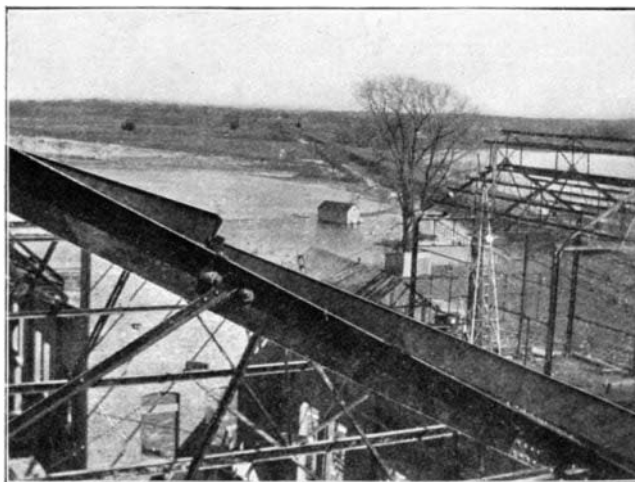
ties. From the works of the Edison Company to those of the Reading Company is a distance of about fifty miles, and with the exception of the eastern end the bed as developed does not appear to be over three or four miles in width. In appearance the argillaceous limestone resembles slate, and in chemical composition it varies within the following limits:

Silica (SiO <sub>2</sub> )	10.00 to 19.00
Alumina and Iron Oxide (Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub> )	4.50 " 8.00
Lime (CaO)	38.00 " 49.00
Magnesia (MgO)	1.00 " 2.00

The next in order of output is limestone and clay, large works manufacturing Portland cement from these materials being located in New York, Ohio,



OPENING UP MARL BEDS.



STEEL ROOF OVERLOOKING MARL LAKE.

worth using, but to put up something that is effective and cheap, this formula cannot be beaten.

#### PACKAGES FOR PASTE AND LIQUID.

As for the packages, the liquid preparation must have a sprinkler top, which in the trade is commonly called a "bug top." This is fastened to each bottle, and is then inserted in place of the cork when the liquid is used. The most convenient package in which to dispense the paste is an 8-ounce amber bottle with a mouth large enough to freely insert a No. 3 painter's sash-tool. You can furnish a brush with a package or not, as you choose. To prevent any tampering with the contents of the bottle a neat paper bottle-cap would be practical and would add much to the appearance, and very little to the cost of the package. The label must bear the name of the preparation, and the directions for use. In writing the matter for the label, make sure to impress upon the purchaser the necessity of thoroughly washing the bedroom furniture and woodwork with plenty of soap and water before making a thorough application of the

ture of Portland cement are lime, silica, and alumina, the last two being generally supplied by some form of clay or shale, the average ratio being one part clay to four parts carbonate of lime.

In the United States the lime used in the manufacture of Portland cement is found in several forms, which may be classified under three general groups—argillaceous limestone, marl, and limestone—the latter group being capable of considerable subdivision.

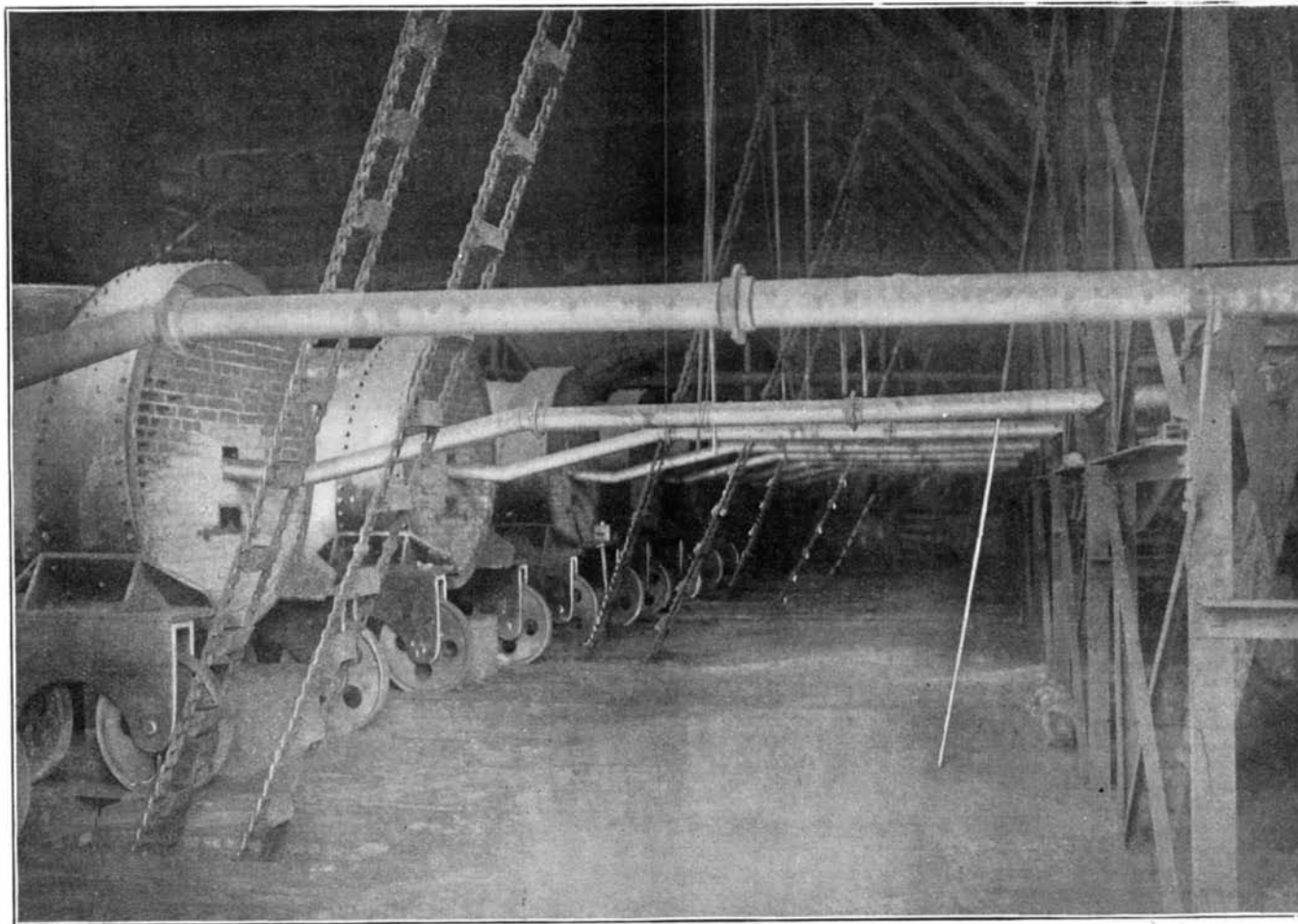
Considering these in the order of their relative importance in the cement industry, the argillaceous limestone is easily first, although its supremacy is threatened, the output decreasing from 72 per cent of the production of the United States in 1900 to about 61 per cent of the estimated production for 1903. The principal deposit of this material is found in eastern Pennsylvania and New Jersey. The most eastern development is at New Village, where the Edison Portland Cement Works are located. The Vulcanite and Alpha Works are a little south and nearer the Delaware River. The next development is at Nazareth, where a number of works are in operation and in course of

Illinois, Virginia, Indiana, Missouri, and other States, all erected in the last four or five years, forcing marl cement from second place in 1902.

The last in the present order of output, but probably second in amount of capital invested and men employed, is marl. Perhaps a fourth should be added—furnace slag—from which considerable cement is being manufactured. Slag cement is manufactured in two ways: One method is simply a mechanical mixture of slag with hydrated lime, and the cement so manufactured is more correctly a puzzolana. By the other method a true Portland cement is produced, the slag being treated as a low-grade limestone, to which sufficient lime is added to secure a correct analysis, the raw materials being ground, mixed, and burned the same as for Portland cement.

The mechanical equipment of a cement plant varies with the raw materials used, each requiring a different treatment; but the general principle is the same, the object being to secure a fine grinding and thorough mixing of the raw materials previous to calcination.

In the dry process which is used for argillaceous



BATTERY OF ROTARY KILNS—WITH FUEL PIPING AND ELEVATORS FOR HANDLING HOT CLINKER.

paste to all the cracks and crevices about the room and furniture; success can be guaranteed if this course is taken. Allow me to remind you of one particular point in getting rid of bugs of all kinds, a point that many a cleanly housewife does not thoroughly understand: a thorough use of soap and water about the woodwork and furniture of the house will often alone exterminate these household pests. Of course, it is not necessary, for obvious reasons, to tell your customers this.

Your liquid preparation is the one you must boast

construction, and the deposit can be traced across the country to the Lehigh River at Siegfried. Here are located the various works of the Coplay, Atlas, American, Lehigh, Lawrence, Whitehall, and Bonneville cement companies. There is no development of the deposit between here and the works of the Reading Cement Company at Molltown, which is probably due to the fact that there are no adequate railroad facilities.

\* Paper read before the Engineers' Club of Philadelphia and published in its Proceedings for April, 1903.

limestone, limestone and clay, and slag, you have as a rule hard materials which are fairly constant in their chemical composition and carry comparatively little moisture, while in the wet process which is used principally for marl the materials dealt with are soft in character, often semi-liquid, carrying, as they come from the deposit, from 40 to 50 per cent of water, and, with some methods of dredging, more. After calcination there is no great difference in the nature of the clinker, and the finishing departments of the different types of mills would be interchangeable.

Marl is of organic origin, the deposits being found in low lands, marshes, and the bottoms of lakes. In texture it is smooth and soft, varying in consistency from that of putty to that of river mud. While the greater majority of the shells are entirely decomposed, about 90 per cent of the marl under ordinary conditions being found fine enough to wash through about a No. 100 sieve, some of the shells still retain their form. The majority of these resemble the ordinary snail shell in appearance, and vary in size from 1 and 2 inches to those that are almost microscopic. In addition to these are found the shells of the fresh-water mussel, apparently of more recent date, which are sometimes as large as your hand. I submitted some of the shells taken from a deposit in Michigan to the Academy of Natural Sciences in this city, and Mr. H. A. Pilsbry wrote me in regard to them as follows:

"The shell-fish mentioned in your letter of November 20, as found in a marl deposit in Michigan—viz., *Planorbis campanulatus*, *Planorbis parvus*, *Limnæa stagnalis*, *Limnæa humilis*, *Physa ancillaria*, *Amnicola lustrica*—are all still existing as living species. The marl in question is doubtless a comparatively recent deposit occupying the bed of a post-glacial lake or pond. Similar deposits occur in northern New Jersey, where the beds of post-glacial ponds have become filled with calcareous material, largely molluscan shells.

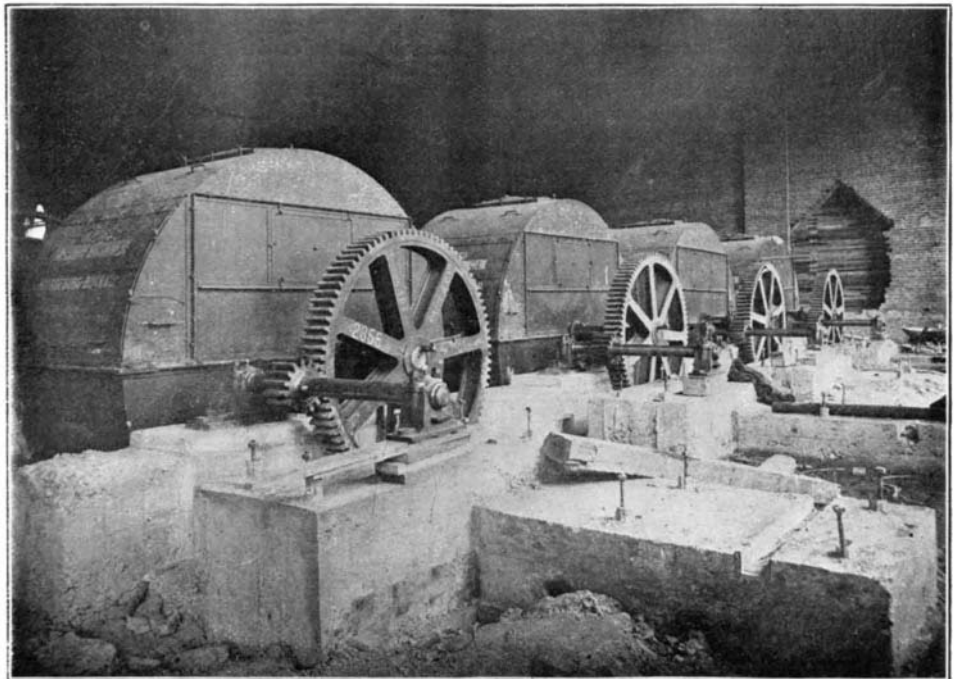
"The cooler climate and great number of ponds and lakes which followed the glacial period favored the multiplication of fresh-water mollusks, which at that time were evidently more abundant than at present, now that the vast majority of these ponds have become extinct by cutting down of streams to their beds and diminished rainfall, etc. However, the same shell-fish may still be found in many Michigan lakes to-day. As a general rule, it requires some search to find them, except in early spring and in the fall, when they are abundant enough in suitable places."

I have never observed any living specimens in the deposits examined, except a few of the ordinary fresh-water mussel.

In northern Ohio, near Sandusky, the marl deposits are of a different character, being largely of a chemical origin formed by the crystallization and deposit of lime through evaporation of the water which overflowed the low lands in periods of flood, etc. Springs in this neighborhood, which come up through the clay

of crystallization and afterward decomposed, leaving in the travertine a cast of the plant. These stones are found in conjunction with granular marls, and are often of considerable size. I have only seen marl of

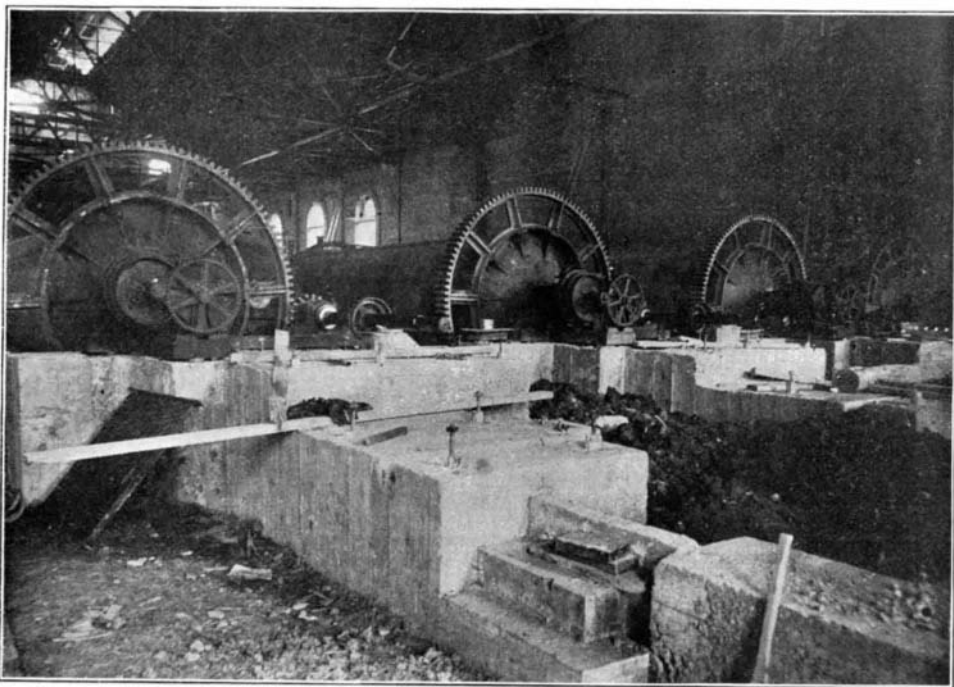
They would appear to have flourished best in shallow waters, and it will generally be found that where the water is over thirty feet in depth there is no marl under it, although fluctuations in the depths of the



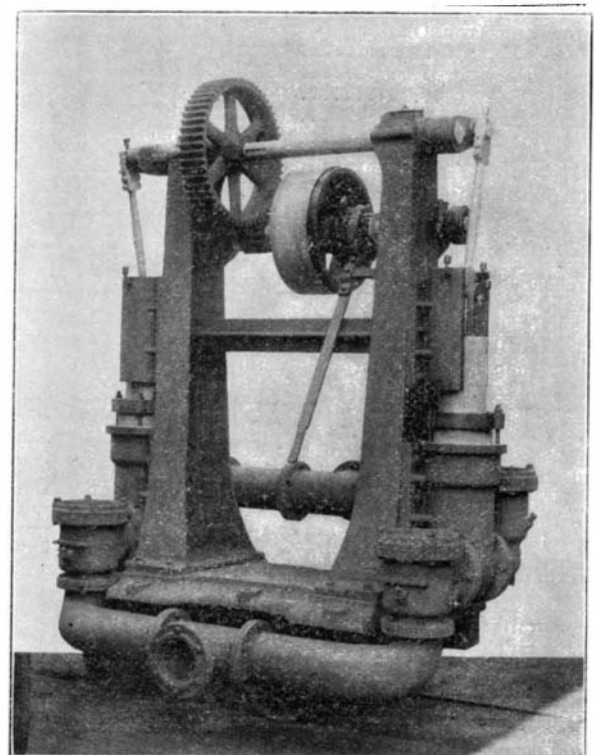
CLINKER GRINDING MACHINERY—BALL-MILLS.

this character in the vicinity of Sandusky, but there are deposits in New York State and elsewhere. In the organic marl deposits small quantities of travertine are found, generally under water in shallow places, the precipitation being probably due to chemical action caused by plant life.

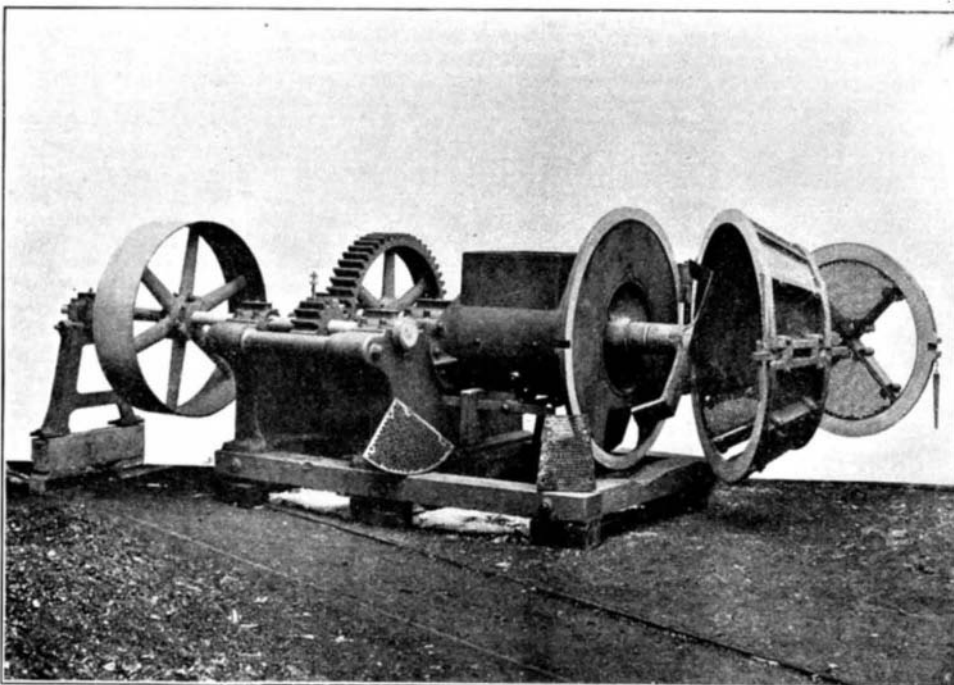
lakes may cause this rule to be departed from. I have observed that almost all of the lakes have an old beaver dam at the mouth, which at a later period had been reinforced by the dams of the lumbermen, which are now falling rapidly into decay. From the appearance of the deposits I would imagine that the various



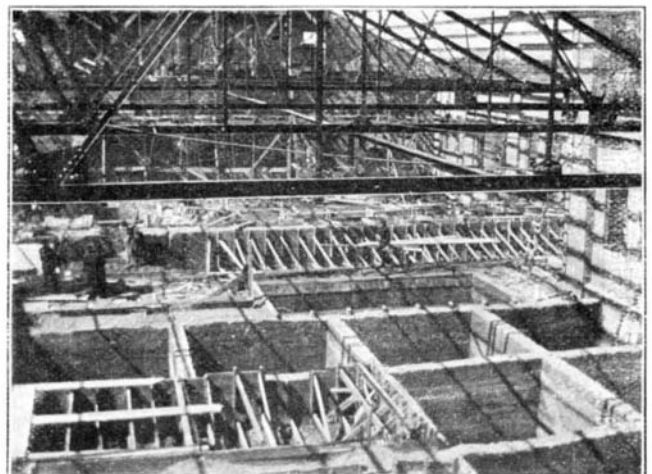
CLINKER GRINDING MACHINERY—TUBE MILLS.



CYLINDRICAL PUMP.



STONE AND GLASS SEPARATOR FOR MARL.



MIXING TANKS.

subsoil, carry a high percentage of lime, in some instances as high as forty grains to the gallon. Large pieces of considerable hardness are frequently found, and these are known locally as prairie rock or petrified marl, and they resemble coral in their general appearance. On breaking pieces of this rock, the outline of rushes and water plants can be followed, which have apparently been incrustated during the process

The deposits of marl vary in size and depth and in many instances are covered with several feet of muck. The mollusks, from the shells of which the marl is formed, must have been very abundant at the time of the formation of these deposits, as myriads of shells would be required in their formation, and the conditions immediately following the glacial period must have been exceptionally favorable for this form of life.

species of mollusks flourished along the edges in the shallow water, and gradually encroached on the lake itself, although it is possible that through the work of the beavers already mentioned the shallow lakes were gradually increased in depth and the marl deposits built up in this manner. With the exception of the presence of vegetable matter near the surface, there is no apparent difference in the analysis of marls



taken from the swamps and low lands and from the lakes, where it was covered from one to ten feet with water.

The deposits vary in depth from a few inches to thirty feet, but should average at least ten feet for profitable working. The surface above low water and shallow portions of the lakes are generally covered with a vegetable growth, the peat and muck running from a few inches to several feet, and this has to be stripped before the marl is excavated. If the water is over two feet in depth, the marl is generally clean.

There are few lakes or swamps in Michigan, northern Indiana, and the various portions of Canada bordering on Lake Huron, Lake Erie, and Lake Ontario, that do not contain marl to more or less extent, and I know of one deposit in Lake Huron itself. This deposit in Lake Huron is rather curious and is located a few miles north of Alpena. It has formed between a small island and the main shore. Drifting sands have practically closed the channel at one end, and the entire bay inside was filled with marl to a depth of about ten feet. The marl, however, was very soft, and an oar stuck upright in it would sink through it by its own weight. While the shells from which the marl was formed were practically pure carbonate of lime, the chemical composition of the marl varies, due to the amount of vegetable matter it contains, and also to silica, which appears to have been blown in by the wind in the form of sand. Sometimes the sand is found in layers and at other times it is mixed through the marl itself. Its presence does not seem to have been caused by the wash from streams feeding the lakes, as the marl is found to be as pure, if not purer, at the mouth of streams emptying into the lakes, as in other parts. While the vegetable matter does not directly affect the quality of the cement produced, as it is burned during calcination, it affects the value of the deposit commercially, as marl high in vegetable matter requires more fuel in its calcination and a greater bulk of marl has to be handled. If the sand is found in any large quantities—say over 3 per cent—it is very objectionable, as unless finely ground it will not combine with the lime during the passage through the kilns, and, when finely ground, it requires a higher temperature to secure combination with the lime. Marl varies in its chemical analysis considerably, but for the successful manufacture of cement it should be within the following limits:

Silica (SiO <sub>2</sub> )	00.00 to	3.00
Alumina and Iron Oxide (Al <sub>2</sub> O <sub>3</sub> + Fe <sub>2</sub> O <sub>3</sub> )	trace	5.00
Lime (CaO)	45.00	56.00
Magnesia (MgO)	00.00	1.50
Sulphuric anhydride (SO <sub>3</sub> )	00.00	1.00
Organic matter	00.00	5.00

Marl deposits are plentifully scattered throughout the States bordering on the Great Lakes and in Canada, the eastern limit seeming a line drawn from Syracuse, N. Y., to about one hundred miles east of Kingston. The western line extends into Illinois and up into Wisconsin, the southern limit being two hundred miles from the Great Lakes. On the north, in Canada, marl is rarely found at a distance of over one hundred miles from the great lakes. I do not know of any deposit north of Lake Superior.

At all the larger mills the marl is excavated by mechanical means, some form of dredge or steam shovel being used. Marl is transported to the mill in various ways. If the surface of the deposit is above water and sufficiently firm, tracks are laid and cars are used; but if soft and covered with water, it is either pumped direct from the dredge to the mill or loaded into scows, in which case it is generally pumped from the landing to the mill, the method of handling varying with the conditions at each plant and the ideas of the designer.

The first mills built to manufacture Portland cement from marl and clay in the rotary kilns attempted the preliminary drying of the raw materials before grinding and mixing, but the results, so far as I can learn, were not satisfactory, due possibly to the fact that when these earlier mills were built, the cement industry was in its infancy and mechanical devices for its manufacture were not so fully developed as at the present time.

The question of drying the marl previous to the manufacture of cement is again being taken up, and I understand several mills are being designed on this principle, and one or two small ones are in operation. While there is no question in my mind as to the mechanical practicability of the drying of marl as the first step in its manufacture into Portland cement, I question whether it will be found as economical as the wet process, or will ever be commercially successful, and await with interest the results in a large mill now being built near Bay City, Michigan, where I understand it is proposed to dry the marl at the deposit, ship it a considerable distance by rail, and then manufacture it into cement. The conditions at this deposit, however, are more favorable for the success of the experiment than any other I have ever seen, as the lakes in which the marl is found are so located that with comparatively little work the outlet streams can be lowered and the water drained from the lakes. The deposits were examined by the writer's firm some years ago, and it was suggested that the outlets of the lakes be lowered, a channel cut the entire length of the lake, from which others would run at right angles to the shore, and that in this condition it might gradually dry out.

A rough experiment was made to determine the effect of drainage of the marl. A considerable quantity of marl was piled in a room, the temperature of which was about 70 deg. or 80 deg. F., but the moisture was lost very gradually. After two weeks a sample was taken from the center of the pile, and on the moisture being determined it was found to contain 32 per cent, the marl originally carrying about 50 per cent, and I question whether by any system of drainage the moisture in the marl could be reduced much below 30 per cent.

In the manufacture of cement from marl and clay it is necessary to add a considerable amount of silica and alumina, which is generally furnished by clay. For the wet process this is preferably plastic in character, and should be low in magnesia and lime and

free from sand and pebbles, the combined iron and alumina in the clay being from one-half to one-third of the silica.

In the vicinity of marl deposits there is generally an abundance of clay, but it is difficult to find a deposit suitable for the manufacture of Portland cement, the majority carrying an excessive amount of magnesia, and where the magnesia is low there is apt to be an undesirable percentage of unavailable silica present in the form of sand. A number of mills started without giving the clay-supply careful consideration, and are now compelled to bring their clay from Ohio.

Shales are found in Michigan which are of good chemical composition for the manufacture of cement, but I know of no plant which is using them for their clay-supply.

Turning to the mechanical construction of a marl plant, the first problem that confronts the designer is the excavating of the marl and the delivery to the mill. This has been treated in several ways, continuous bucket dredges, dipper dredges of the clam-shell or the orange-peel type, pneumatic or hydraulic dredges all being used, but the latter process has not been found as successful as the other, owing to the large percentage of water brought up with the marl and the difficulty of separating the muck and other impurities from the marl. In some plants the marl is dredged and submitted to the preliminary preparation on the dredge, the marl being afterward forced through a pump line to the mill. Probably the most successful machine for the preliminary preparation of the marl is one resembling a mammoth sausage-grinder, which in its principle is identical with the "Universal" meat-chopper. The machine consists of a hopper of sufficient size to receive from 1 to 2 yards of marl at a time. Underneath this hopper is a powerful screw conveyor which forces the material against a perforated plate, the holes in the plate being about one-half inch in diameter. The soft marl is forced through these holes, while the grass, roots, stones, etc., are discharged from the bottom.

I have had no personal experience with the pumping of marl from the dredge to the mill, but understand that the most successful device is a double cylinder with compressed air, the marl itself acting as a piston, the device consisting of two tanks which are alternately filled and emptied. After the tank is filled, the compressed air is turned on and the contents forced into the pipe line. In the mills where I have been connected with the design, the conditions have favored the handling of the material in cars, as the greater portion of the marl deposits were above water. Tracks were laid out on the marsh and the cars run directly to the dredge, a mattress of brush being used on the softer parts. On reaching the mill the marl is dumped into a separator or pugging conveyor, thoroughly breaking it up; the marl, which is now in a semi-liquid state, being about the consistency of grout, is stored in tanks or concrete pits. The clay, which is generally brought from some distance, is then added to the marl in correct proportions. It has been customary to dry the clay, grind it, and mix it with the marl at the pug mill, but in the mill of the Detroit Portland Cement Company, which has just been started, a departure was made and the drying omitted, the two materials being reduced to a slurry separately.

On delivery at the mill the clay is first passed through a disintegrator and then into a pugging conveyor, where sufficient water is added to bring the clay to about the same consistency as the marl, and the clay is run to storage tanks, from which it is pumped with the marl into the mixing tanks, the proportion being roughly one cubic foot of clay to four cubic feet of marl. In the mixing tanks the slurry is subjected to thorough agitating, and the slurry is then ground to such fineness that 95 per cent will pass a No. 100 sieve.

The handling of the raw materials after delivery to the mill is done by pumps, three types being in use—cylindrical pumps, centrifugal pumps, and compressed-air pumps—as previously described.

For grinding the marl the wet tube-mill has been most generally used, although in some of the Canadian mills which I visited this fall millstones were used with excellent results. After grinding, the slurry is stored in large tanks, where a final analysis is made, and if necessary the mix is corrected. From these tanks the slurry running from 40 to 50 per cent of solid matter is pumped directly into the kilns, where it is dried by the waste heat, this drying taking place in the first twenty feet of the kilns. Kilns for burning by the wet process are generally made longer than those used in the dry process. The stack temperatures in the wet process are considerably lower than in the dry process, and operation shows that the calcination of the slurry consumes considerably more coal than in the dry process. I am of the opinion, however, that this increased coal consumption is not entirely due to the amount of water in the slurry, but to the more refractory character of the raw materials, and to the decreased production. In one mill some experiments were carried on to determine stack temperatures in connection with the consumption of coal, and it was found that with a stack temperature of about 400 deg. F., the best all-around results were obtained. In the dry process the stack temperatures run from 800 deg. to 1,200 deg. F., and, if the kiln is being forced, even higher.

The use of powdered coal in the burning of cement has now become almost universal, and with the exception of one or two small mills in California and Texas, oil has been entirely superseded. One mill is operated on natural gas, but I have been unable to secure any data as to capacities and outputs.

In ordinary practice the burning of cement by the wet process is more expensive for two reasons: First, there is an increased consumption of at least 50 pounds of coal per barrel of cement produced, and a decrease in production per kiln of about 50 per cent. While some mills claim to be producing by the wet process 125 to 135 barrels per kiln per day, I do not think the average is much more than 100 barrels per kiln; while by the dry process a production of over 200 barrels per day per kiln is not unusual, and I should think an average of the production of all the dry mills would show that 175 barrels has been at-

tained, with a coal consumption of about 110 pounds, some mills where the material is easily fused dropping as low as 90 pounds.

I was very much surprised to see a record of one week's run in a cement mill recently that showed, with five kilns in operation, a production of 256 barrels of cement per kiln for each twenty-four hours, with a coal consumption of 89 6-10 pounds of coal to the barrel of cement produced. I think that record is greater than any I have ever heard of, and it is an absolutely correct one, as all the coal is weighed going into the kilns and all the cement coming out.

After burning the clinker, the process of manufacture differs in no way from that in use in the dry plants, the marl plants having an advantage over the dry plants from the fact that the clinker is more readily ground.

Comparing the manufacture of cement from marl and clay with the manufacture of cement from the argillaceous limestone of the Lehigh region, or from limestone and clay, the principal advantages and disadvantages are as follows:

In the manufacture from marl and clay the excavation and grinding of the raw materials are much less difficult, as the materials are all soft; but to counter-balance this you have the following disadvantages:

First, with each 100 pounds of raw material you have to handle 100 pounds of water.

Second, after starting manufacture the raw materials cannot be left at rest, but must be agitated.

Third, an increased fuel consumption of 50 per cent.

Fourth, difficulty of operating in cold weather.

Fifth, reduced production per kiln.

These offset any advantages gained by the softer character of the materials.

This general review of the conditions will serve to make the accompanying illustrations clearer and more easily understood.

The marl is excavated by a clam-shell dredge with a bucket capacity of 1½ yards, which discharges into the cars. These cars are brought to the foot of a double-track incline, up which they are drawn to the second floor of the marl building, which has an elevation of about 40 feet above water-level in the lake. The hoist has a sufficient capacity to haul up two loaded cars, the empty cars returning by gravity. The cars are dumped into a hopper over the separator previously described, and from this they discharge into an 18-inch ribbon conveyor which carries the marl to the six separate pits, each of which is equipped with a two-arm agitator revolving at a speed of fifteen revolutions per minute. Compressed air is being substituted for mechanical agitators in a number of the mills, and considerable advantage is claimed for its use.

The clay is brought in by the rail, and is unloaded directly into the hopper of the disintegrator, which is located in a building not shown on the plan. After passing through the disintegrator, the clay is discharged into an 18-inch cut flight conveyor, which, in addition to conveying the clay to the clay storage pits, thoroughly pugs it. It was originally intended that the clay should be discharged into a wash-pit which was equipped with an especially designed four-armed agitator similar to the wash mill used in Europe, the arms being equipped with drags; the outlets are so arranged that the washed clay could be discharged into three adjoining storage pits. It was, however, found on operation of the mills that the clay was so thoroughly disintegrated and pugged before delivery to the wash-pit, that further treatment was unnecessary, and the clay is now delivered into any of the separate pits without first going in the wash-pit, two of the arms in the wash-pit agitator having been removed. Each of these pits has a capacity of about 1,600 cubic feet. From the storage pits the material discharges through pipes by gravity to the suction of the two pumps located just in front of the storage pits for marl and clay. When mixing the raw materials, a sufficient quantity of clay is first pumped into one of the four mixing pits, then the marl is added; these pits are equipped with high-speed propeller agitators, the two pumps being so piped that one can be working on marl and one on clay at the same time, or both on one material.

After the marl is added to the mixing pit, the mass is agitated for about thirty minutes, and then a sample is taken, the percentage of lime determined by volumetric methods, and, if the mix is correctly proportioned, the contents of the pits are pumped to three steel storage tanks located over the tube-mills on a platform, if no correction is needed.

The material from these tanks is fed by gravity to the tube-mills which discharge into the five slurry storage pits. The total storage represented by the various pits is sufficient to produce 2,500 barrels of cement. The entire proportioning of the raw material is made previous to the grinding, although check analyses are taken from each pit after grinding in order to prevent the possibility of error in the mix.

From the storage tanks the finished slurry is pumped to the kilns, an even pressure being maintained by two stand-pipes through which the overflow returns to the pit from which the slurry is being pumped.

The rotary kilns are of the ordinary type, six feet in diameter, sixty feet long. Each kiln is equipped with a speed regulator, by which its speed of rotation may be varied from one turn in forty-five seconds to one turn in three minutes.

The clinker after passing through the kilns is discharged into the vaults located directly under the kilns, which are of sufficient size to admit of the kiln operating for four days without removing any of the clinker. It was hoped when the plant was designed that this storage would be sufficient to allow of the clinker cooling sufficiently to be delivered directly to the ball-mills. To better secure this end it was intended to force cold air into the bottom of the pits and exhaust it from the top. Experience elsewhere, however, developed the fact that the mass of clinker was so great that thorough cooling could not be obtained, the air seeking preferred channels, and an auxiliary system was put in, rotary coolers being used. The fans exhausting from the top are those used for blowing the powdered coal into the kilns, the air used for this purpose being heated by its passage through clinker. A considerable improvement in the opera-

tion of the kilns is effected, and consequent saving of fuel, the temperature of the hot blast being about 700 deg.

The coal is unloaded directly from the cars to an elevator, which discharges it into the hopper of a rotary drier, from which the material is discharged into a disintegrator which reduces it to such fineness that the majority of it will pass a No. 10 sieve. From this disintegrator the coal is elevated to the bin over the tube-mill, where it is ground to such fineness that 95 per cent will pass a No. 100 sieve. From the tube-mill the coal is elevated and discharged into the coal bins in front of the kilns.

The grinding machinery differs little from the standard practice, ball- and tube-mills being installed in this instance. Griffin mills are also frequently used. The entire plant is electrically driven, twenty-six motors being installed, the tube-mills, ball-mills, and other large machines having individual motors which belt directly to the driving pulley of the machinery. The elevators, conveyors, etc., are all arranged in groups, and driven through countershafts to which the motors are belted. General Electric current motors being used, varying in size from 15 to 100 horse power. The power plant is equipped with four 200 horse power Wickes vertical boilers, two 500 horse power Russell engines, and two 300 kilowatt General Electric generators, and it is contemplated in the near future to install an additional engine and generator, as the present generators and engines are loaded up to their limit, and there is no opportunity to shut off for repairs.

The plant was started in operation on October 1, and cement was ready for shipment October 15. The plant is at present only operating five kilns, as owing to a fire which destroyed the works of one of the sub-contractors, the delivery of three kilns is delayed, and they are not yet ready for operation.

The buildings are non-combustible in construction. The raw material and kiln rooms are built of brick with steel roof trusses and corrugated iron roof; the balance of the buildings are of steel and corrugated iron.

Although advocates of the wet process are enthusiastic regarding the value of marl as a cement-making material, and in the Michigan district no other material can secure a hearing, and the same condition prevails in the Lehigh region in regard to the argillaceous limestone or cement rock, I notice a growing tendency to favor limestone and clay. The mills manufacturing from these materials are widely scattered, so the growth of this portion of the industry has attracted so little attention that there may be many who will question the statement that 22 per cent of the cement manufactured in 1903 will be produced from this material. The use of limestone and clay is not confined to new enterprises, two of the largest manufacturers in the Lehigh region having erected mills in the West, and their estimated production for 1903 is 5,000 barrels per day.

The following approximate table shows the amount of cement manufactured from the different materials in the past five years, and also the growth of the cement industry for that period, and I would not be surprised if the next few years show even greater gains for limestone and clay.

Date.	Argillaceous limestone.		Marl.		Limestone.		Total.
	Production.	Per cent.	Production.	Per cent.	Production.	Per cent.	
1899	4,100,000	73	1,200,000	21	300,000	5	5,600,000
1901	8,700,000	70	2,150,000	17	1,850,000	13	12,700,000
1903 (estimated)	11,600,000	61	3,200,000	17	4,200,000	22	19,000,000

[Continued from SUPPLEMENT No. 1432, page 22951.]

ON ELECTRONS.\*

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PART VI.

ELECTRIC THEORY OF MATTER.

Estimate of Size of Electrons.

On the hypothesis that the flying or vibrating fragment is a material corpuscle charged with electricity, so that it has a duplex constitution and a compound kind of inertia, part material and part electrical, no further progress can be made. But on the hypothesis that the flying or vibrating particle is an electron—a charge of electricity and nothing else—a constituent of an atom but with no material nucleus—so that the whole of the atomic properties are to be considered as due to an aggregate of electrons of opposite size, of which one or two are comparatively free and detachable—on this hypothesis a determination of the mass of a corpuscle carries with it as a consequence a determination of its size also.

Because, as has already been pointed out, any required amount of self-induction can be conferred on a wire by making it fine enough, and any required amount of energy can be conferred upon an electric charge by making it concentrated enough. The energy at a given speed of motion will be proportional both to the quantity and the potential, and the latter can be made as great as we please by making the size of the body possessing the charge extremely small.

It is the intense region of force close to the wire or close to the charged particle which is the effective region; and so, as stated, a knowledge of the mass or kinetic energy at a given speed suffices, on a purely electric theory of matter, to determine the size of the electron constituents of which it is composed. For whether there be any intrinsically material inertia or not, there certainly is an electrical inertia. The cause of it in the electrical case is known; it is due to the reaction of the electric and magnetic fields

during acceleration periods, and is denominated self-induction.

Quite possibly there is no other kind. Quite possibly that which we observe as the inertia of ordinary matter is simply the electrostatic inertia or self-induction of an immense number of ionic charges or electric atoms or electrons.

This is by far the most interesting hypothesis, because it enables us to progress, and is definite. The admixture of properties, partly explained (viz., the electrical), partly unexplained (viz., the material), lands us nowhere, unless by some only partially imagined means we were able to estimate how much of the corpuscle appertains to each ingredient.

The mass of a corpuscle has been measured at something akin to 1-1000 of an atom of hydrogen, and its charge as  $10^{-20}$  electrostatic unit. This amount of electricity will have that amount of inertia if it exists over a sphere of radius  $10^{-13}$  centimeter, but not otherwise. Consequently we may assume the size of the electron to be of the order  $10^{-13}$  centimeter in diameter; or 1-100000 of the linear dimension known as molecular magnitude, viz.,  $10^{-8}$  centimeter.

With a size like that the penetrating power of cathode

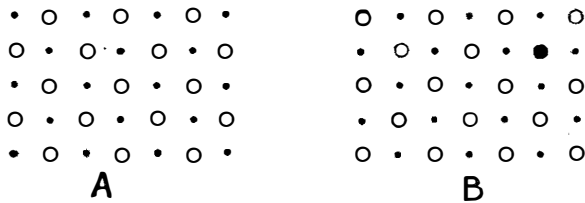


FIG. 5.—ORDINARY COHESION BETWEEN TWO NEUTRAL ATOMS A AND B: EACH ATOM CONSISTING OF INTERLEAVED ELECTRONS OF OPPOSITE SIGN, DEPICTED IN ANY CONVENIENT WAY.

rays is explained. Especially if the atoms of matter are themselves composed of such minute particles. For the interspaces will be enormous compared with the filled-up space, and a point can penetrate far into such an assemblage without striking anything.

It can be determined by considering how much space the substance of all the electrons in an atom occupies, as compared with all the space which the atom occupies itself. In other words, we have to consider what the size  $10^{-13}$  for an electron's diameter means, as compared with the size  $10^{-8}$  for an atom's diameter. In the solar system the diameter of the earth is 1-20000 part of the diameter of its orbit round the sun. Consequently if the earth represented an electron, an atom would occupy a sphere with the sun as center and five times the distance of the earth as radius.

In other words, if an average atom is composed of electrons, they are about as far apart in that atom in proportion to their size as the planets in the solar system are in proportion to their size.

In an atom of hydrogen there are roughly 1,000, or say more exactly 700 electrons in order to make up the proper mass.

In an atom of sodium, which is twenty-three times as heavy, there must be about 15,000 electrons.

And in an atom of mercury there must be over 100,000 electrons.

Consider then an atom of mercury containing 100,000

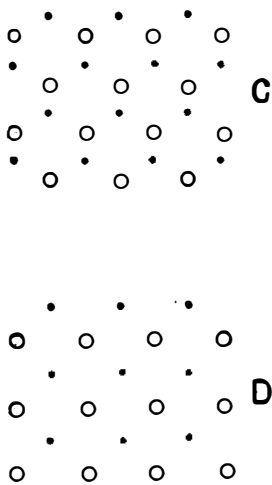


FIG. 6.—TWO POLARIZED ATOMS, POLARIZED IN DIFFERENT WAYS; ILLUSTRATING ALSO ELECTRICALLY INTENSIFIED COHESION.

of these bodies packed in a sphere  $10^{-8}$  centimeter in diameter. One would think at first they must be crowded; but there is plenty of room. Each electron is only  $10^{-13}$  centimeter across, and there are only about fifty of them in a row along any diameter of the atom; hence the empty space inside the atom is enormously greater than the filled spaces. At least a thousand times greater in linear dimension, or a thousand million times greater in bulk.

The whole volume of the atom is  $10^{-24}$  c.c., the aggregate volume of all the electrons composing the atom is  $10^5 \times 10^{-30} = 10^{-24}$  c.c.; consequently the space left empty is  $10^{10}$  or ten thousand million times the filled space.

Even inside an atom of mercury, therefore, the amount of crowding is fairly analogous to that of the planets in the solar system. For though the outer planets are spaced further apart than the inner ones, they are also bigger, to practically a compensating extent.

From what is sometimes called Loschmidt's theorem in the kinetic theory of gases, the mean free path of an electron inside an atom of mercury will be  $10^{-4}$  centimeter; that is, it may get through on the average

the substance of some 10,000 mercury atoms in a row without collision.

In any other less dense substance it will go further. The actual distance thus traveled by corpuscles plunging into a dense metal is very small, only the thousandth part of a millimeter on the average, and it need by no means necessarily be a straight line; so a target of platinum succeeds in stopping them fairly near its surface, and enables the X-rays generated by the shock fairly to emerge. Some corpuscles will be stopped more suddenly than this, and some will travel further, but  $10^{-4}$  centimeter is about the average distance traveled in a solid as dense as platinum.

This distance, however, gives no notion of the value of the negative acceleration during a collision, because the greater part of the thousandth of a millimeter is free flight; the stoppage occurs only as the last episode of that flight, viz., at the instant of collision. The colliding masses are 100,000 to 1, so the change of velocity at impact could be estimated; but the impact will really be more of an astronomical or cometary character, and the effect is analogous to the entrapping of comets when they pass near a planet, thereby rendering them permanent members of the solar system.

The ordinary behavior of a foreign comet, which comes and goes, may be called a collision with, and rebound from, the sun; for although there is no real encounter of main substance, that is what it would appear like if it could be seen from the depths of space; and the two branches of the comet's hyperbolic orbit would look like straight lines of approach and recession.

Comets which happen to pass very near a planet, however, are deflected, swirled round, and often virtually caught by that planet, receding only with an insignificant differential velocity which is unable to carry them away from the attraction of the sun; into which they often drop. Or if they do not actually drop into it, they will continue to revolve round it in an elliptic orbit, becoming a member of the solar system, and liable ultimately to be degraded into a swarm of meteors.

This is the sort of process known to occur in astronomy, and circumstances not unlike that may attend the encounter or apparent collision of a furiously flying comet-like electron with part of the massive system of an atom.

The stoppage, therefore, will occur well within the limits of atomic magnitude,  $10^{-8}$  centimeter; and so

the acceleration will be of the order  $\frac{u^2}{2l} = 10^{20}$  c.g.s.,

and the force needed thus to stop even a single electron will be the tenth of a dyne.

No wonder that violent radiation-effects are produced. The "power" required to stop an electron, flying with one-thirtieth of the speed of light, inside a molecular thickness, can be estimated as  $10^8$  ergs per second, which is equivalent to ten watts. (Though the time it lasts is only the  $10^{-17}$  part of a second.)

But only a small fraction of this goes into radiation. The rest, therefore, it would appear, must take the form of heat.

Effective radiating power depends chiefly on very sudden stoppage, and on the speed being near that of light. If the velocity is a tenth that of light, and if an electron can be stopped in something like its own diameter, about 10 per cent of the energy will go in radiation, and the rest will take other forms, presumably heat.

As the velocity diminishes, more and more of the energy takes the form of heat; which agrees with the fact that at moderate vacua the target gets red-hot.

The ratio of the radiation power to the total power is as the dimensions of an electron to the distance light would travel during the period of the stoppage. So to get all the energy radiated it is necessary to stop a pellet moving with a tenth the speed of light in something like a tenth of its own diameter.

JUSTIFICATION FOR ELECTRIC VIEW OF MATTER.

But now what justification is there for the extraordinarily far-reaching hypothesis that the electrons constitute matter, that atoms of matter are composed of electric charges, that the fundamental inertia-property of matter is identical with self-induction?

There is the reasonable philosophical objection to postulating two methods of explaining one thing. If inertia can be explained electrically, from the phenomena of charges in motion, it seems needless to require another distinct cause for it also. But this is not all that can be said; it is quite possible that direct experimental proof will be forthcoming before long. A method suggested by Prof. J. J. Thomson had reference to the proportion of radiation to thermal energy developed when corpuscles encounter a target which suddenly stops them. In so far as they consist of non-electric matter they would produce only heat by their dead collision, without any direct generation of ethereal waves. In so far as they consist of electric charges they would disperse a certain amount of radiation energy; and so the proportion of radiation to heat might afford a criterion. Hitherto, however, no adequate measurements have been made in this direction.

But there is another more likely avenue to a conclusive result. We know that when an electric charge moves with a speed approaching that of light, its inertia is theoretically no longer constant, but rapidly increases and becomes infinite when the light-velocity itself is reached, at least on the orthodox and accepted theory; and rather complicated and not quite accordant expressions for this high-speed inertia have been calculated by several mathematical physicists.

It is possible that in certain cases of the production of cathode rays a speed not far short of that of light may be reached, and the increased inertia observed. Such an experimental determination has been seriously and quite recently undertaken by Prof. Kaufmann, who employed the method indicated above of comparing simultaneously the electric and the magnetic deflection of the same set of rays submitted alternately or simultaneously to an electric and a magnetic field. Thus the velocity and the  $e/m$  ratio are both known, and Kaufmann concluded that when the speeds ap

\* Excerpt from a paper read before the Institution of Electrical Engineers and published in the Journal of Proceedings of the Institution.