SCIENTIFIC AMERICAN SUPPLEMENT. No 1503

Entered at the Post Office of New York, N. Y., as Second Class Matter. Copyright, 1904, by Munn & Co.

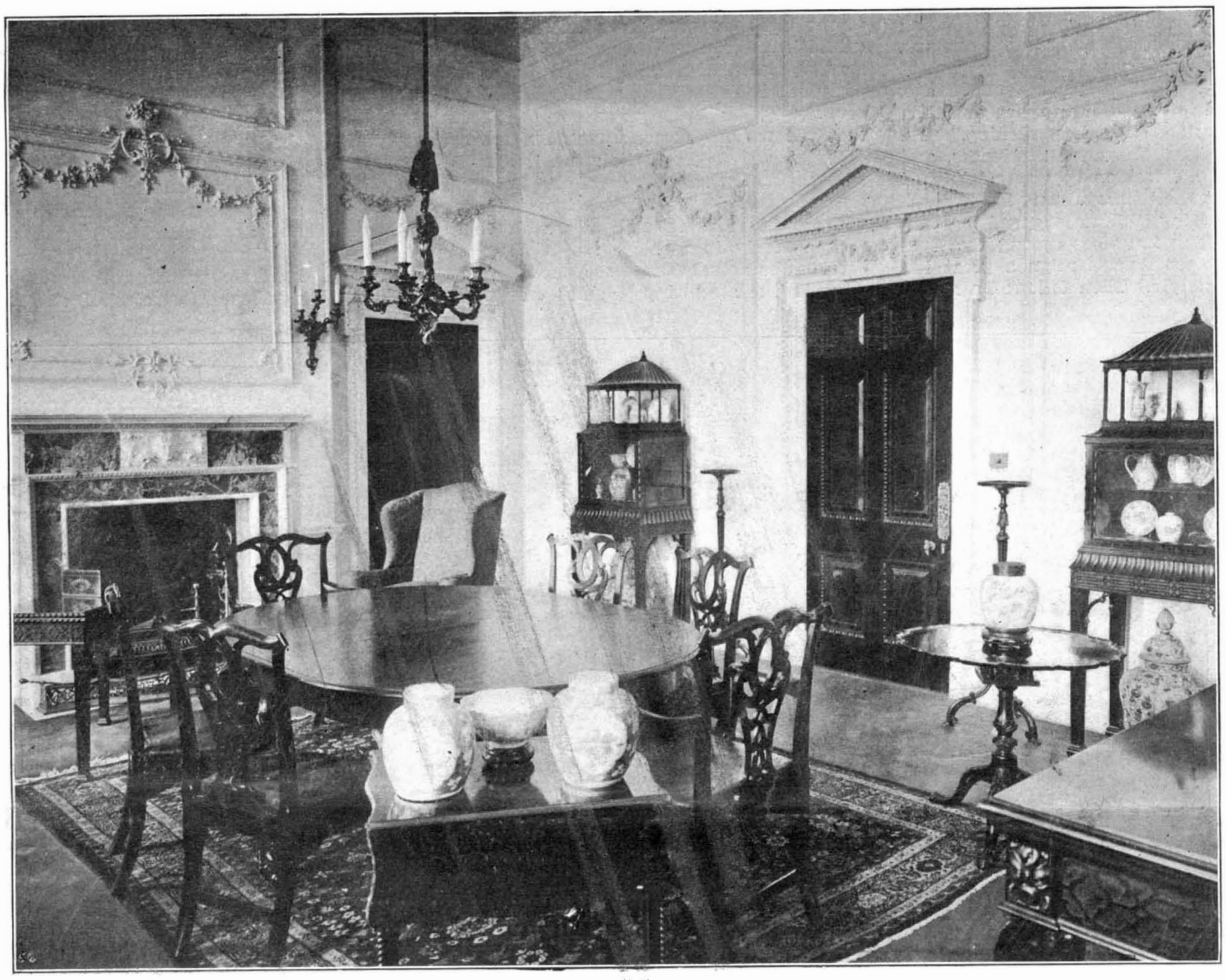
Scientific American, established 1845.
Scientific American Supplement, Vol. LVIII., No. 1503.

NEW YORK, OCTOBER 22, 1904.

Scientific American Supplement, $5 a year.
Scientific American and Supplement, $7 a year.

THE BRITISH PAVILION AND EXHIBIT AT THE ST. LOUIS FAIR.

It was a happy thought of the Royal Commission that is responsible for the British exhibit at St. Louis to reproduce as the national pavilion one of the most beautiful of the buildings in the gardens surrounding the historic Kensington Palace, the birthplace of the late Queen Victoria. The Orangery, as it is called, is considered by English critics as one of the most beautiful examples of Renaissance architecture in London, if not in all England. It is an ideal representation of the Queen Anne style of architecture, the plans being drawn by Sir Christopher Wren and revised and approved by the Queen herself. The Orangery was designed for a greenhouse; and although it was built two hundred years ago, it is considered to-day to be one of the finest specimens of garden architecture in England.



ENGLISH INTERIOR IN THE BRITISH PAVILION.

The total exterior length of the building is 171 feet and the width 32 feet. As a specimen of an unaffectedly ornamented exterior of brick, the front elevation, aiming rather at simplicity and plain dignity than magnificence and grandeur, is admirable. In the center is a section more elaborately treated than the rest with four rusticated pillars supporting an entablature of the Doric order. Above the cornice, over the central doorway, is a semi-circular window, apparently designed to give light to the roof. The main body of the building is lighted in front by eight lofty windows, and at each end are slightly projecting wings or bays with window doors of extra height, reaching to the floor level in

Copyright 1904 by Louisiana Purchase Exposition Company.

THE BRITISH GOVERNMENT PAVILION AT THE ST. LOUIS EXPOSITION.

order to admit tall grown oranges and other plants. These are flanked by rusticated piers. A similar arrangement of windows and niches is repeated at the ends of the building.

The main building at St. Louis is made larger than the original orangery by the construction of wings extending back from either end. In plan the long main hall ends in circular anterooms. The internal walls have niches, panels, and fluted Corinthian pilasters, with carved capitals and cornices. The interior of the building is largely taken up by the necessary offices and accommodation for the Royal Commissioners and the executive staff. But it also contains several handsome displays of interior decoration and furnishing, one of the best of which is shown in the accompanying engraving.

In the gardens surrounding the pavilion an attempt has been made to reproduce, on a small scale, the style of garden that was generally attached to the mansion residences in England during the reigns of William III. and Mary, at the close of the seventeenth century, and at the time of Queen Anne in the early part of the eighteenth century. William, Prince of Orange, was responsible for the introduction of what was then and has since been termed "Dutch gardening." He introduced this style about the royal residences, and it was not long before the fashion became established and general throughout the country. The Dutch landscape gardeners whom King William engaged to carry out his ideas found many imitators among the English, so that during Queen Anne's reign a great impetus was given to this style. Then followed a school of landscape gardeners opposed to the Dutch ideas of design; and consequently many fine examples were destroyed to give place to what was termed the "natural" style, in which formality and straight lines were abandoned for irregularity. Queen Anne gardens were a pleasing combination of the Tudor, Jacobean, and Dutch style. Their characteristic features were stately terraces, shady avenues, formal parterres, inclosed by hedges clipped into shapes, and embellished with the forms of animals and birds cut out of yews and box. The fashion became a craze, and it was carried out to such an extent that it came under the scathing ridicule of Pope, and after that it declined.

There is a charm about a genuine old formal garden which appeals to most people, and the general idea of such a garden is exhibited in the British Pavilion garden, of which our illustration gives a faithful impression.

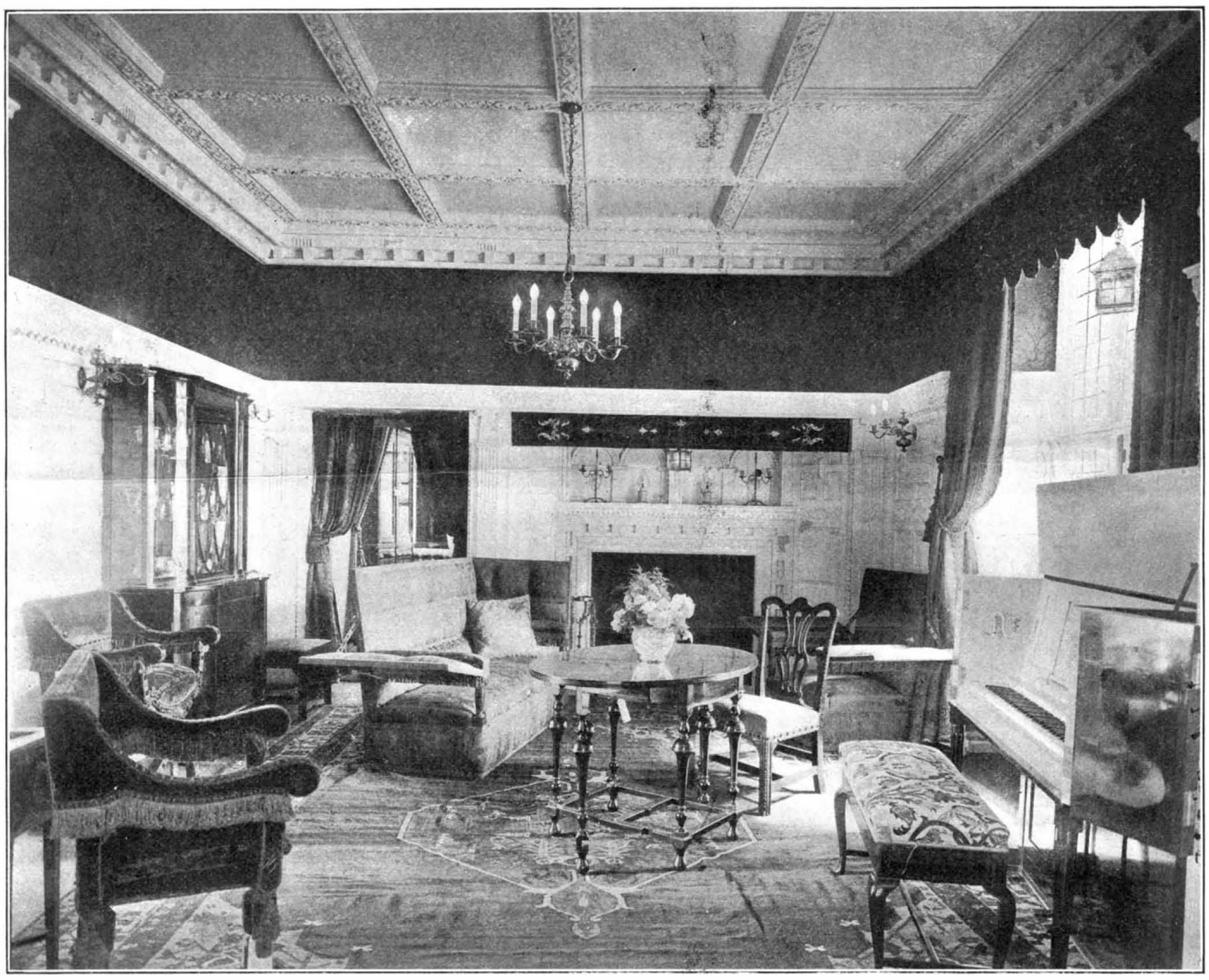
Next in importance and interest to the Pavilion and gardens is the exhibit of the jubilee presents of Queen Victoria, which are housed in the Hall of Congresses, which forms one of the group of Administration Buildings. The splendid collection of tributes to the Queen sent from every province of the Empire is exhibited in a score of large cases, which are under the protection, day and night, of a detail of London police. Here may be seen richly bejeweled caskets from India and costly souvenirs from Ceylon, Australia, South Africa, the finest of the last-named being a magnificent ivory casket, upon its lid a gold spray composed of the rose, the shamrock and the thistle, which flashes with 212 diamonds from the Kimberley mines. The value of the Jubilee exhibit alone is put down at $6,000,000.

The British Commission are justly proud of the exhibit which they have made in the Educational Building, not so much because of its size, but on account of its thoroughly representative and instructive character. It treats broadly of education as carried out in Great Britain, and every possible branch of the widely-varied types of schools and methods of instruction is delineated, either by photographs, or by the work of the students, or by statistical and diagrammatic comparison. The exhibit ranges from the board schools of London, whose roll contained 884,610 names, to statistics, views, and objects of interest from the ancient universities of Oxford and Cambridge.

In the Palace of Varied Industries the skill of the English artisan in the textile arts and in the manufacture of furniture and general upholstering is demonstrated in a well-chosen and extensive exhibit. One of the most frequented sections is that in which the exhibiting firm have grouped their material within a reproduction of a complete English house. The proportions of the building are those of the conventional country house; but once inside the visitor is aware that the various rooms have been treated in widely different styles. Thus the salon is a noble apartment with magnificent furniture of the Empire style; there are bedrooms furnished and decorated, some of them with great richness and others in the simple and comparatively inexpensive styles. Two of the rooms contain the actual furniture, paneling and ceiling that were in the steamship "Ophir" on which the Prince and Princess of Wales made their trip around the world. Beyond this house is a fine display of embroideries, silks, laces, etc., which was gotten up by the British Royal Commission with a view to illustrate the use of these fabrics for specified purposes. The exhibit is arranged in a court that is flanked by lofty glass cases. The exterior contains a series of panel paintings illustrating the costumes from the sixteenth to the nineteenth century.

An interesting display is that in the Palace of Mines and Metallurgy, where by means of large maps and statistical figures and a collection of photographs of high merit, the workings and extent of England's great coal industry are portrayed. The output of this industry amounts to 230,000,000 tons a year, produced by an army of 900,000 men. One of the most complete exhibits is a set of machinery, shown in active operation, which illustrates how the raw cotton is made into spun yarn; and in another building, that of Agriculture, there is a creditable display of machinery and plant, showing in its daily operation the manufacture and baking of breadstuffs.

Of course it was natural to expect a handsome display from Great Britain in the Transportation Building; but there is considerable disappointment over the fact that there is not a single good-sized English locomotive on exhibition. What is lacking in transportation by land, however, is somewhat compensated by the really excellent display made by the steamship companies, which consists chiefly in an array of glass cases containing beautiful models made to scale of modern ocean passenger steamers. Lastly, mention should be made of the low-temperature exhibit of the British Royal Commission. It is housed in a separate building of its own, in which the liquefaction and solidification of hydrogen is regularly demonstrated. In bringing the hydrogen to the liquid and then to the solid state there are four stages. The first cooling is done in the carbonic acid chamber, when the temperature is lowered to —70 deg. C.; the second stage of —190 deg. C. is reached in the liquid-air chamber; in the third stage, the liquid air and exhaust lower the temperature to —205 deg. C.; in the fourth chamber the hydrogen by self-cooling is reduced to —252 deg. C., at which it liquefies, and finally, by the exhaustion of the liquid hydrogen, the solidification of the gas is achieved at a temperature of —257 deg. C. In connection with this exhibit lectures on the subject are given in the nearby Liberal Arts Building.



MORNING ROOM OF ENGLISH COUNTRY HOUSE IN THE PALACE OF VARIED INDUSTRIES, ST. LOUIS.

THE MANUFACTURE OF PEAT BRIQUETTES.

THE peat fuel industry has been left to a large extent to individual enterprise, mostly in rural districts of Germany, Netherlands, Scandinavia, Russia, and Ireland, and any statistics that have been issued on the subject are untrustworthy. The use of peat as fuel in Germany dates back to the earliest history of the Teutonic tribes. The peat bogs cover very extensive areas in the northern temperate regions of Europe and America. The German peat area is estimated to be about 11,000 square miles; and peat is utilized for hygienic purposes, for manufacture into paper-stock, cardboard, felt, alcohol, etc., for burning in gas generator furnaces, and for manufacture into peat coke, peat slabs and carbonized briquettes. The manufacture of peat slabs has been practised in a crude way by peasants in the north of Germany and in Holland for more than a century, for the purpose of obtaining a cheaper and more efficient fuel than wood or cut peat. During the past fifty years this industry has been placed on a more intelligent basis, due chiefly to the solution of the problem of a cheap production on a large scale. At the present day machine peat is made which stands transportation and the influences of weather and in many localities even competes with coal. According to a report by the American Institute of Mining Engineers, the method of making machine peat is entirely automatic, the machinery for cutting the peat, elevating it to the press, and conveying the slabs to the drying ground being mounted on a truck which travels into the bog sometimes under its own steam. This arrangement is made for a capacity of from 50 to 80 tons in 24 hours, and costs from £800 to £1,200 at the factory. The truck travels on rails, and the bog is gradually exhausted by cutting each new trench next to the one just completed. An excavating elevator drops the raw peat into the machine where it is disintegrated, kneaded, and forced through a mouthpiece in the form of an endless plastic band, upon a truck on which it is cut, by a series of adjustable knives, into any desired lengths. The pressure required is very slight, and, as no water escapes, the chemical composition of the raw material is unchanged. The volume of the peat is reduced about one-half, and the slabs, when thor-

oughly air-dried, weigh from 40 to 60 pounds per cubic foot. One man is employed for every two or two and a half tons of peat briquettes produced. While the raw peat contains as a rule between 80 and 90 per cent of moisture, the air-dried slabs have seldom more than from 15 to 25 per cent. To effect a more thorough drying, large hot-air chambers are used. The cost of making machine-peat in Germany is from three to four shillings per ton at the outset, which allows a considerable depreciation for the machinery. This figure is taken from the Schilt Works, near Oldenburg, and from the Ranbow Works, near Langen, on the Elbe. There is a peat bog at Magdeburg, which yields annually about £540 worth of machine peat per acre, while the cost of manufacture is but £180, thus leaving a profit of £360 per acre. The average depth of this bog is 40 feet. The experience gained with the use of press-peat as locomotive fuel in Bavaria, Austria, Sweden, Russia, and Ireland, is stated to be very satisfactory. The utilization of dried press-peat for gasmaking and as a substitute for coal and charcoal is also stated to be satisfactory. The problem, to produce from a poor grade of fuel containing from 70 to 90 per cent of moisture a briquette which can compete with coal, or can make up deficiencies in the fuel supply, is a very serious one. Huge masses of raw material have to be handled and cleansed from foreign matter, and tons of water have to be expelled in order to obtain a limited quantity of valuable fuel. Many processes have been tried and abandoned as they proved to be too expensive. A few plants in Germany and Holland are working on similar lines with brown coal, but a large portion of the water is expelled mechanically before drying by heat. Much labor and money have been expended in Germany on the development of the peat industry, and nearly all modern methods have originated in that country. Great efforts are being made to establish the manufacture of solid peat briquettes as a permanent commercial industry. In Holland there are many acres of peat bog excavation under cultivation, and supporting from 300 to 350 people per square mile. In some water-filled bog trenches, fisheries are established on a large scale.—Journal of the Society of Arts.

THE CHEMISTRY OF FATS.

As chemistry continues to study the phenomena of nature more narrowly, it becomes easier to trace the condition and gradual transformation of the substances which play a part in the lives of plants and animals. To the great distribution and the assimilation and transformation of carbon and nitrogen combinations, long since discovered, is added a series of less striking transformation processes, the study of which, however, is not less interesting.

The true synthesists among the living organisms, who can produce organic matter from inorganic elements, and who perform this task on a most tremendous scale, are plants. Whether animals are at all able to transmute inorganic matter is at best questionable. At any rate, directly or indirectly, the greater part of the corporeal substance comes from the plant kingdom. The rabbit who is at home in the cabbage-field subsists entirely upon vegetation, but the fox who hunts the rabbit and would not touch a blade of grass, grows fat upon the body of the little animal nourished by plant life. Consequently, we may find even in the bodies of the typical beasts of prey not a few things whose origin can with certainty be traced to the activity of vegetation. Hence we must commence at plant life if we wish to observe the substances which, through their characteristic properties and their immutability, are capable of being followed in their wanderings through a series of living beings. Fats belong to those substances which even the most primitive plant cell regularly produces, and which therefore, little as we have been able to ascertain about the process of their production, may be considered typical products of life processes. Indeed, there is hardly a plant cell which, when microscopically examined, does not show imbedded in the gelatinous mass of the protoplasm those small, shining spots which are nothing else than freshly-formed fat. Liebig rightly did not neglect the fats in his fundamental observations concerning the chemical processes in animal and plant bodies. He considered them among those substances which in later epochs of existence could, where necessary, be consumed, and which thereby serve to produce heat and energy. To a certain extent we to-day recognize this rôle, and, surely, the supplies of fat which many plants and animals here and there store up in their bodies are primarily intended for this purpose. Not always, however, is this intention carried out. It is a fact of no little significance that the fats contained in the organisms which are constantly perishing by the thousands of millions are better able to withstand decay than albumen. Consequently, it is rather easily fossilized, and becomes the source of one of our most important mineral products, namely, mineral oil.

The fat which in this manner has been removed from the great circulation of life will not be discussed here, but the fat which, with the plants that formed it, normally enters the bodies of the animals that feed on the plants. For a long time it was believed that animals could produce fat, if not from inorganic matter, at least from certain organic substances, which they assimilated with their plant food. To-day, most physiologists, as far as I know, no longer hold this view, but believe that the fat, even that stored up in such quantities by certain animals, was taken up entirely with the plant food of these animals, and in special circumstances is stored up for future necessity for heat. The marmot, which during the summer and early fall wreaks destruction among the herbs of the mountains, in fall is a fat creature. If, however, the vigilant animal escapes the bullet of the hunter and seeks its lair to hibernate during the frigid Alpine winter, it subsists for nearly half a year upon its supply of fat, and reappears in the spring as a thin but consequently more agile animal, to recommence the work of gathering fat. It cannot be said that the herbs upon which this animal lives are especially rich in fat, but the microscopic globules of fat which are present in the cells of these plants, as well as of all others, suffice, if gathered systematically, to form the bacon-sward of the little inhabitant of the rocks in the course of half a year.

We have been familiar with the chemical nature of the fats since the classic investigations of Chevreul. We know that wherever they may be found, they are not simple substances, but are mixtures of materials which are, it is true, very closely related. The fats are collectively glycerides of the fatty acids; this accounts for the similarity of their properties, and for the fact that it is so difficult to tell them apart, or even to separate them quantitatively. They may easily be saponified, that is, again separated into their principal components, glycerin and fatty acid. In the laboratories we avail ourselves of the powerful action of strong alkalies and acids for this purpose. Our modern chemistry has taught us that nature, which does not like to work with such powerful means, employs milder but no less effective agents. By their aid she decomposes the fat, concealed in the seed of the hidden and immature plant, which has been given to it in the lobule to serve as the first means of nourishment. The bacteria, which for their purposes attack the fats and thus effect their renascence, work in a similar manner.

These are all well-known facts. Indeed, Chevreul already recognized the characteristic features, and our modern investigations only confirmed and developed the knowledge of this great chemist. Chevreul, however, entirely overlooked or was unsuccessful in explaining the fact that all fats contain a small percentage of matter that cannot be saponified. This is similar to the case of the argon of the air, which Cavendish had already observed over a hundred years ago, but had not sufficiently examined. It was not till our own time that the phenomena were studied and explained. Chevreul and the industrial chemists who have followed in his footsteps knew and constantly observed that the fats could not be entirely saponified. In later days the nature of these unsaponifiable constituents was discovered, and we recognized in them two of the fatty acid esters of two alcohols differing from glycerin, namely, cholesterine and isocholesterine. Since this, we have designated the unsaponifiable substances which are mixed with all fats as cholesterine fats, or if the raw material comes from the plant world, as phytosterine fats. They are remarkable because of several very striking reactions besides being unsaponifiable, and consequently are very easy to recognize and identify. We now have in these cholesterine fats a means of discovering and observing more closely the circulation of the fats in living nature than has heretofore been possible. In consequence of their unsaponifiability, they are practically unattackable; they are, therefore, frequently found as the last residue where the ordinary fats have in great quantities been used up, worked out, and finally burned up. A few examples will show this.

Let us observe the circumstance of the assimilation of the fats in the organism of a purely herbivorous animal, for instance, the sheep. This gentle animal, as is well known, is subject to so little mental excitement that practically all its waking hours are devoted to taking food. Enormous quantities of grass are eaten and digested in the course of time, and with the milliards upon milliards of plant cells which in this manner enter the body of the animal, the numerous globules of fat which are stored up in the protoplasma of these cells are also introduced into the circulation of the body. The protoplasm is normally changed into blood and fibrin; the fat is used up to produce the bodily heat of the animal and to furnish the living force for the movements of its limbs. A certain part of this fat is also stored up in the body, and forms the fat rolls or cushions, which we regard so highly in a well-prepared mutton roast. But by far the greater part is consumed for the above-mentioned purposes. However, the admixture of phytosterine present in the plant fat escapes the combustion because it is attacked with difficulty and is unsaponifiable. The percentage of this is, of course, very small, but as it is not consumed it gradually accumulates, and consequently must somewhere be discovered again. If one were to seek this waste product of the natural fat consumption in the body of the animal, one might be inclined to believe that it would be found stored up in the cushions of accumulated fat. But nature does no such thoughtless work, for these supplies of fat are intended to serve as a reserve in time of need, and therefore should not be made difficult to assimilate because of the useless addition. The expedient that nature has devised is astonishing; if it had been the product of a human mind, it might have been called the thought of a genius. The sheep separates the unattackable phytosterine fats by means of the sebaceous glands of its skin, and impregnates therewith the wool that covers it. By this means the latter becomes pliant and difficult to wet. The gentle animal is saved the labor of consuming the almost indigestible portion of the fat, and besides makes good use of it, in that its fleece is sufficiently oiled and protected from cold.

In working up the shorn fleeces of the sheep, we again find the separated phytosterine fats. They are known as sweat of sheep's wool or wool-fat, and by the quantity—they constitute about one-half the total weight of the raw wool—we can approximately conceive how enormous was the mass of the fat that the animal took up with its food in the course of a summer, and consumed for the maintenance of its bodily heat and movement.

It is generally known to-day that the wool-fat, formerly a troublesome waste product of wool washing, now is the raw material for a great industry, which removes from it the cholesterine fats in a state of great purity. Thus they are introduced to commerce under the name of "lanoline" and offer a superior base for salves and other epidermic remedies, for leather polishes and many other purposes, particularly for such where it is a question of thoroughly impregnating skin and skin products. Animal skin takes up this fat, which is unsaponifiable and unchangeable, more readily than any other.

This last is by no means remarkable, as the sheep, by means of which I have just demonstrated the enriching of the cholesterine fats, is not alone the possessor of this method of separating the same, but it is found without the least difference in all animals. Everybody knows the peculiar soapy feeling which we perceive after having stroked a dog or a cat, or even by some chance have handled a fowl. The skin, the hair, and the feathers of these animals are impregnated with cholesterine fat, and the same is true of our own skin, which does not appear quite so greasy only because the most of us happily have the habit of washing oftener than the above-named creatures. When the swan swims through the wind-ruffled lake, the drops run from his feathers without wetting them, and we may see a similar state of affairs in every aquatic song bird. This condition is produced by the fat, and in fact the cholesterine fat, which collects in the feathers of the birds exactly as the "sweat" in the sheep's wool. If we approach the cage of a parrot or of a bird of prey in a zoological garden, these animals frequently beat frantically about them with their wings, and thereby surround themselves with a cloud of white dust. This is nothing else than cholesterine fat in such a hard condition that it lies on the animal's skin in scales, and is thrown off as a powder upon violent motion of the body.

The organism does not always succeed in putting aside in so simple a manner the entire mass of the phytosterine, which remains in the body as the remnant of the consumed fats. For instance, if the normal ability of the body is disturbed through sickness, the removal of the unsaponifiable parts of the fats offers great difficulty. In such cases though, the liver, the fat-consuming organ of the animal body, makes frantic endeavors to saponify the cholesterine fats as well as the others; it is only partially successful in doing this. In consequence there occur accretions of such fats or rather of the cholesterines separated from them, accretions which happen very frequently, not only in man, but also in animals, even if they are only actually found in extreme cases. These form the well-known gall-stones, which may even endanger the life of their possessor if they become large in size. In an isolated condition they are curiously beautiful objects, and if they are crushed, are found to be formed of snow-white, glistening, silky crystals of pure cholesterine.

There can be no doubt that the plants in producing the fat do not work only in the interests of the animals who are destined to destroy and eat them. They need the fat for their own life process, even if more sparingly so than the animals do. Similarly as with animals, they are unable to work out the cholesterine fats as easily as the normal glycerin fats, and consequently they must take care of them differently. In doing this they have evolved a method which bears a certain similarity to the methods employed by the animals. Mixed with wax, another fat constituent which I have not mentioned until now for reasons of simplicity, the phytosterine fats exude in an excessively thin layer upon the surfaces of the leaves and stems of the plants. For this reason these organs are very difficult to moisten. Thus their fatty covering prevents the leaves, when the dew forms upon them during the morning hours, from drowning, by protecting the excessively delicate breathing-pores. Only a long, steady rain is able thoroughly to wash the thin fatty layer from the leaves, and meanwhile the pores have had time to close through the swelling of the cells which surround them. The phytosterine covering lies so thickly upon fruits, especially dark-colored ones such as plums, cherries, and grapes, that we can see it with the naked eye as an exhalation. Indeed, if we examine them with the microscope, we can frequently recognize the spots where the bees have gnawed away the wax and fat to carry it off with them to build their honeycombs with it. A freshly-picked apple is greasy to the touch, just as is a cat or a dog, and for the same reason. If we rub the apple with a soft woolen cloth, it glistens exactly like the coat of an animal pet when we brush it frequently. Certain plants even resemble the sheep, in that they separate out the wax and phytosterine fat in such quantities that man collects it, and may truly regard it as a welcome gift from nature. This is the case with many tropical plants, especially the famed Carnauba palm, which, when shaken by the wind, drops a veritable shower of wax flakes, which are then gathered by the inhabitants of the country and placed upon the market.

The manifold uses of the fats have called forth industries in all lands, in which thousands of tons are

used yearly. But we must calculate in thousands of millions of tons the fat that is never touched by the hand of man, but is used up in the household of living nature as quickly as it is produced. We see the traces of this tremendous energy, which we cannot observe in its entirety because of its infinite distribution, in the cholesterine fats, which in their repeated appearances indicate to us the path that the circulation of the fats has taken in the united circulation of life.—Translated for the Scientific American Supplement from Prometheus.

MODERN METHODS OF STEEL CASTING.*

By Joseph Horner, A.M.I.Mech.E.

At first sight it might appear that the differences between steel and iron would have little effect on the methods of making the two classes of castings. That, however, would be a very incorrect view; for, beyond the work of making the actual molds, the two methods have little in common. Further, although the actual molding is done on very similar lines in iron and steel foundries, there are yet important differences which separate steel founding as a craft from iron founding. There are variations in the materials of which the molds are made; the metal behaves differently, and has to be treated accordingly; and some matters, such as shrinkage, that are common to both, have more pronounced effects in steel, and are much more troublesome to deal with.

The mechanical details of molding are common to all branches of foundry work. The steel caster adopts the methods of bedding-in, turning-over, machine-molding, and the rest. He rams, vents, mends up when necessary, employs cores, uses ingates and runners, dries the molds, and pours the metal. The mechanical work of steel-molding differs mainly from that of iron-molding in the following particulars: A much larger proportion of steel castings are molded in dry than in green sand—a necessary precaution on account of the high temperature of the molten steel. Steel molds

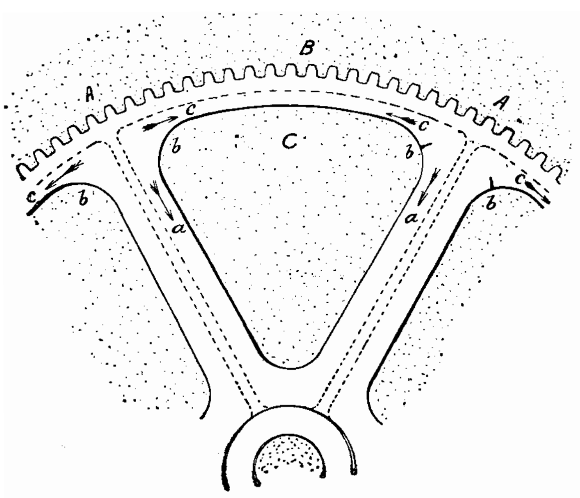


Fig. 1.—Illustrates the Shrinkage of a Steel Wheel.

are rammed harder than those of iron, for the same reason. To withstand the action of the metal, the facing sands and washes must be more infusible than those used for iron molds; nearly pure silica is generally used. Tar is sometimes used for blackening. Large drying pits are required in steel foundries for the heaviest molds, which are made and dried *in situ* when too large to be put into the stove. They are covered over with plates during the drying, which is carried out with gas.

The general employment of steel castings in engineers' work was brought about by the Bessemer process, by which several tons of cheap metal could be produced from molten pig within half an hour. The effect on engineering practice was astonishing. At once firms began to substitute steel castings for those of iron; for gear-wheels especially, and for those more or less flimsy details of work which had previously been forged, or made in malleable cast iron. Bessemer metal lent itself to the production of shapes which

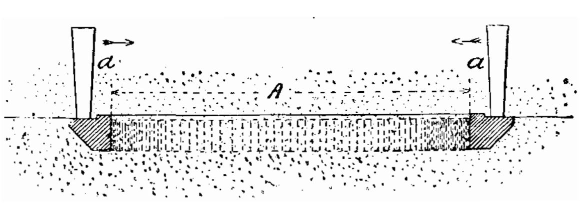


Fig. 2.—Large Ingates on a Steel Casting Hinder Shrinkage.

could be forged only with difficulty and expense. The alternative was the use of malleable cast iron, which is not so strong as steel, nor is its range of strength and ductility so great as that which is obtainable in steel. Steel also displaced cast iron for many articles; it being much stronger if of similar dimensions, or as strong when made of smaller dimensions, with resulting lessening of the weight of mechanisms. It therefore entered into rivalry with cast iron, malleable iron, and forged work. Later, the electrical industry greatly increased the demand for steel castings.

* Technics.

Looking back to that period, the immediate results were somewhat disappointing. The early castings were very hard, very much blown, and the effects of shrinkage were in some cases so pronounced as to render them either useless, or to detract greatly from their strength. After much disappointment, improved methods, and a clearer understanding of the problems to be tackled, were arrived at. Let us first consider the important question of shrinkage; for the troubles of steel casting were, and still are, largely due to the excessive shrinkage of the metal, combined with its lack of fluidity, steel setting much more quickly than cast iron does. We use the term "metal" loosely in this

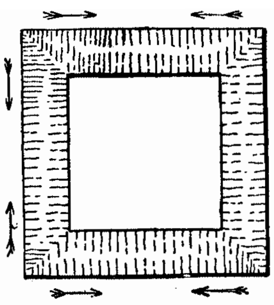


Fig. 3.—Illustrates Weakness Due to Lines of Cleavage.

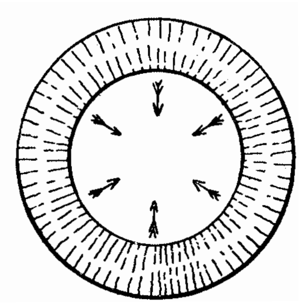


Fig. 4.—The Strongest Form of Casting.

article without apology, just as it is employed in the shop sense. All iron, cast or malleable, steel, and brass constitute "metal" to the founder, although these substances are really alloys.

Taking shrinkage first: its amount in cast steel varies considerably, depending on the chemical composition, the degree of hardness, and the temperature at which the steel is poured. But it may be taken very approximately at ¼ inch to the foot, while that of cast iron is about ¼ inch in 2 feet 6 inches. This is not the only feature by which steel is distinguished from cast iron. The shrinkage of brass is half as much again as that of iron, but it does not give trouble. Every ill connected with shrinkage that affects cast iron influences steel in a far greater degree. Matters are complicated by the fact that steel is cast in very hard dried molds, of which siliceous ganister forms the principal portion, with the result that the castings are tied, and their natural movements impeded. The behavior of steel when shrinking is well illustrated by the sketches here given, selected from notes made of castings which have passed through the writer's hands at different periods.

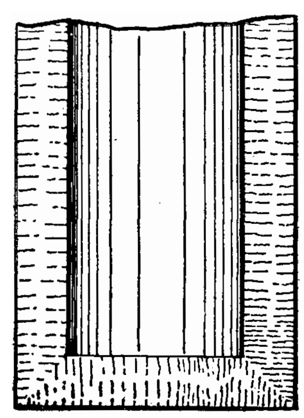


Fig. 5.—A Casting of the Weakest Form.

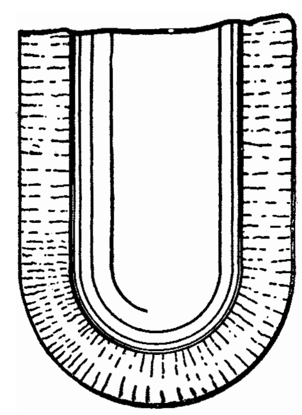


Fig. 6.—A Casting of the Strongest Form.

The mold for the spur wheel, Fig. 1, selected from several of this form, was, of course, truly circular. But the casting came out smaller in diameter at *A*, *A*, in line with the arms, than at *B*, midway between them. This was due to the inward pull exercised by the shrinking of the arms in the direction indicated by the arrows *a a*. The result of this, in wheels of from 4 feet to 5 feet in diameter, was, that opposite every arm the measurement was less by from ¼ to ⅜ inch than that taken across at *B*. The wheels, therefore, had to be turned on the tips of the teeth to remove a portion of the irregularity. Another evil sometimes happens, to prevent which is the object of the large radii at *b b*; at these places minute cracks, indicated on the right hand, are liable to develop in

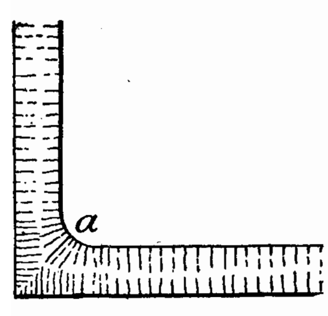


Fig. 7.—A Casting Strengthened with a "Fillet" or "Hollow."

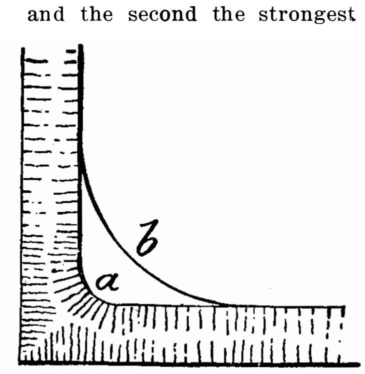


Fig. 8.—A Casting Strengthened with a Fillet and a Bracket.

the castings, due to the pull caused by the shrinkages in the directions of the arrows *a* and *c*. This is got over only by putting very large radii in the corners as shown. The want of circularity in the rims can only be lessened by digging away the sand at *C*, before the metal has cooled down—an important point to which we shall have to refer again.

The effect of shrinkage, restricted to a portion of a mold, is seen again in the ring of internal teeth used for slewing cranes, Fig. 2, in which *a a* are the ingates, the very large dimensions of which are to

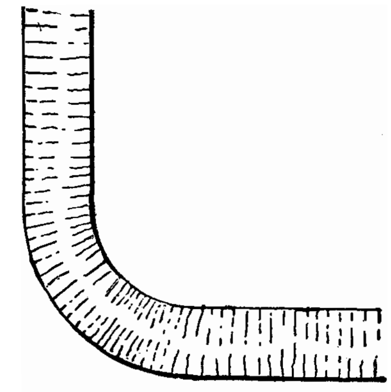


Fig. 9.—Casting Filleted and Mounted.

be noticed. The sand within these tied them fast, and thus they held the ring fast immediately below. The result was, that several of these rings came out elliptical in form, measuring as much as from ½ inch to ¾ inch more in diameter at *A* than they did in a perpendicular direction. Digging away the sand from the inner portions of the ingates at *a a* before the casting had cooled down to a full cherry red, got over this difficulty.

These shrinkage strains cause trouble to the iron founder also, producing distortion, or fracture; or severe internal stress without fracture; but they occur on a smaller scale, and are more easily dealt with. They are of the same character, however, and it will be as well to look into the reasons for their occurrence, and the way to prevent them, or lessen their effects.

The crystals of iron and steel, in cooling, arrange themselves with their longer axes at right angles to the external faces of the metal. It is not difficult, therefore, to tell beforehand where the lines of separation, or cleavage of the crystals, must occur.

On comparing a square frame, Fig. 3, with a circular one, Fig. 4, we see at once that the first is the weakest, and the second the strongest possible form of casting. The shrinkage of the sides of the first tends to widen the natural lines of cleavage between the crystals; that of the second reduces the diameter, and the crystals are simply rendered more compact. Figs. 5 and 6 are forms derived from 3 and 4 respectively, and have their applications in daily practice. To strengthen a section like Figs. 3 and 5 is the object of inserting curves or fillets (Figs. 7 and 8, *a*), or of brackets (Fig. 8, *b*); these play a most indispensable part in the design of castings, both in iron and steel, but especially in the latter substance. The curve *a* obliterates a portion of the sharp lines of cleavage; and though *b* does not change the crystallization, it strengthens an otherwise weak section. The ideal

section is that shown in Fig. 9, so that a nicely filleted and rounded casting is not merely an æsthetic object, but something entirely utilitarian in character.

Of what value are calculations as to the strength of castings that are based only on careful tests, worked perhaps to several places of decimals, when bad designs can bring the castings within an ace of breaking? Sometimes castings will fracture in frosty weather from this cause alone, besides failing under test loads.

There is another matter inseparably related to shrinkage and crystallization, and one which is of equal importance. It is the "drawing" of metal under shrinkage, meaning by this, the pull exercised on interior masses in heavy sections, by the shrinkage of the external parts.

In Fig. 10 we have adjacent heavy and light sections, and whether cast in iron or in steel, the central portions of the heavier section will be "drawn," and be more open than the outer parts; it will frequently be found, on fracture, to be actually destitute of metal, as indicated. To avoid this, care is taken to maintain a supply of molten metal to the thick parts during shrinkage, by sinking heads, by feeding, and by pouring fresh metal into the runner as the cooling proceeds.

These draws can be foreseen, though it is often difficult to avoid them. Invariably the interior portions of any casting (except the very thinnest, say below 5/8 inch or so in thickness) show on fracture larger

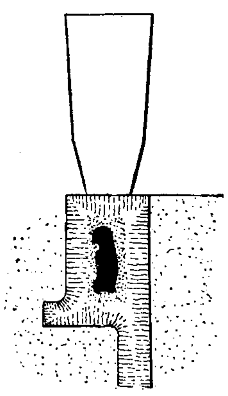


FIG. 10.—A BAD "DRAW" IN THICK METAL.

and coarser crystallization about the central portions than next the exterior. The explanation is, that the inner crystals, cooling slowly, become subject to the pull of those which have already set; when they cannot yield any farther, they part company, leaving central spaces open, as in Fig. 10. If a casting is of similar substance throughout, little or no trouble will arise, because the entire mass will cool more uniformly. It is, of course, impossible to embody uniformity of section, or of mass, in all castings; but the aim must be to approximate thereto as closely as practicable.

We are now in a position to consider some other examples of castings. Fig. 11 illustrates the center bed of a crane, which, if cast in steel in the proportions shown below the line *a a*, would either fracture, in consequence of the shrinkage of the heavy boss, or be pulled concave along the sides, or crack at the angles *b* or *c*; or all these things might happen. But if the sides, which act as ties, are taken away, and the casting is made as in Fig. 12, or of the modified shape in Fig. 13, then, since there is nothing to act in opposition to shrinkage, the casting will remain sound, and will suffer little distortion.

The lower half of the illustration in Fig. 11, which shows a design suitable for iron, can, if modified as in the upper half, be cast in steel. The differences are, that the mass of the boss is much lessened for steel, and that larger radii are arranged in the angles at *b*. A heavy boss in steel (and in a lesser degree, too, in iron) would either increase the distortion of the casting, or help to produce fracture at *b*; while the interior would be honeycombed and open, as in Fig. 14.

The reason why a big boss causes fracture, and

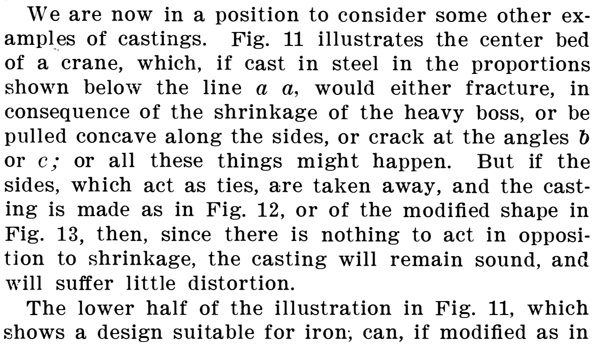


FIG. 11.—AN INCLOSED FRAME, PROPORTIONED FOR STEEL AND FOR IRON.

itself remains open and spongy in the central portions, should be clear from what has been already stated. The thinnest parts of a casting and the outer faces which are in contact with the sand, are the first to cool. These cooled portions, being set rigidly, cannot accommodate themselves to the shrinkage which is going on in adjacent portions. In Figs. 11 and 14, therefore, the comparatively thin webs of the ribs and flanges cool long before the mass of the boss does. The walls of the boss also cool before the interior does. And thus the boss continues to shrink away from the rigid arms, and its interior also shrinks away from its outer faces, so that what will occur is fracture at *b b* (Fig. 11); sponginess in the boss (Fig. 14); and cracks at all the angles of the framing, unless prevented by modifying the shape as seen above, *a a*, for steel.

An inclosed bed or framing like Fig. 11, but having diagonal ribbing like that in Fig. 13, is even more

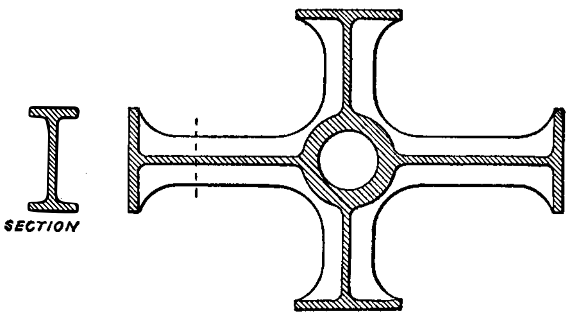


FIG. 12.—AN OPEN FRAME, EASILY CAST.

troublesome to cast than one with ribbing at right angles; for in addition to the shrinkage pull of the metal per foot of length, there is the increased length on which it is exercised, due to the diagonal direction of the bars. Such castings not only give trouble from this cause, but also from the massing of the metal in the corners, where the diagonals meet the sides. Drawing occurs here, in addition to the risk of fracture, as indicated in Fig. 15. This makes a dangerous section, and the metal in the corner will certainly be strained by the pull of the diagonal rib, and will be spongy or open internally.

It might be inferred from the foregoing that there would be no difficulty in making steel castings in which the metal is uniformly thin. But that depends entirely on the shapes required. Provided there is nothing to interfere with shrinkage, as in Figs. 12 and 13, such castings are safely made. But cores interfere greatly with shrinkage, and therefore cannot be cast without risk.

(To be concluded.)

THE UTILIZATION OF NIAGARA POWER.*

IN spite of the possibilities for long-distance transmission use, I believe, nevertheless, that the bulk of Niagara power will always be used within a radius of a few miles of the Falls. It is cheap power that manufacturers want, especially those of electro-chemical products, and the nearer they get to the Falls the cheaper will be the power.

Transmission of power for long distances is expensive at best. Take the case, for instance, of the

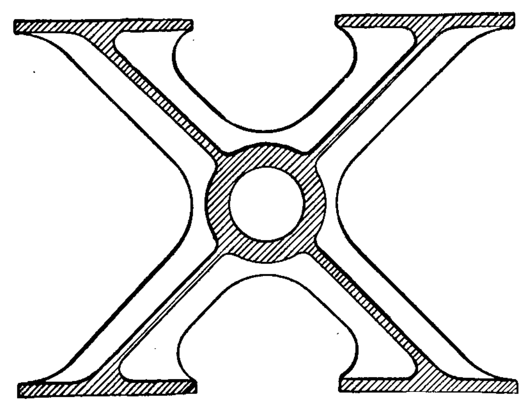


FIG. 13.—AN OPEN FRAME, EASILY CAST.

Niagara-Buffalo transmission. The current, after it leaves the generators, is transformed to 22,000 volts by expensive step-up transformers, which not only waste some of the power, but must be operated and maintained, and interest must be paid upon their cost. From here the current traverses the transmission line over a private right-of-way. This also must be operated and maintained, and interest must be paid upon a large investment in line as well as for right-of-way. Furthermore, power is lost in the transmission. After reaching the city line of Buffalo, the current is again transformed for distribution throughout the city. This distribution is accomplished by means of an extensive system of underground cables. All this apparatus must have fixed interest charges paid upon it, and it requires a large force of experienced men for its operation. When, therefore, the statement is made that not over 10 per cent is lost in transmitting power from Niagara to Buffalo, it does not mean that power will cost only 10 per cent more in Buffalo than at the Falls, for the difference will be much greater than this.

However, even with this transmission cost added, Niagara power is delivered in Buffalo to-day to customers more cheaply than they can produce it themselves by isolated plants. The saving in cost is not the only advantage. The elimination of the steam boiler and engine outfit in a factory by the use of Niagara power is a luxury and a convenience which has many incidental commercial advantages.

When the Niagara enterprise was first started there was a great deal of talk about operating all the factories in New York State by Niagara power. Such a possibility, under the present state of electrical science, is theoretical only; for electric power, transmitted to such distances by present methods, could not possibly compete with steam. In theory, Niagara power can be sent to San Francisco in any amount, but its cost, when it got there, would be prohibitive.

Another argument against transmitting Niagara power to a long distance from the Falls, is that it is not commercially necessary to do so. There will be probably a sufficient market for power within a 50-mile radius of the power-house to use up all the power which has thus far been developed, and it is likely to continue so. It is cheaper for the factories to locate near the Falls than to carry the power a long way to the factories.

One exception to this general tendency against the transmission of Niagara power to long distances is in the case of the steam railroads mentioned above. If they change over to the use of electric power, it is likely that they will use Niagara power within a circle of wide radius about the Falls, possibly 100 to 150 miles. In their case the conditions are peculiarly favorable for long-distance transmission. They will use power on a large scale, and will have their own private right-of-way, without extra cost for the installation of their overhead circuits. Furthermore, they will have to compete electrically only with steam power as developed in the locomotive, which, as is well known, is a very expensive method of utilizing

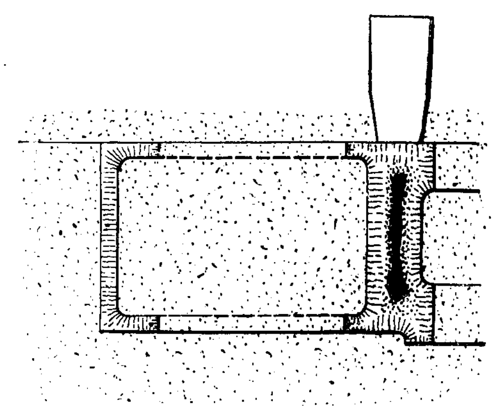


FIG. 14.—HEAVY BOSS, WITH A BAD "DRAW" IN THE CENTER.

the energy of coal, as compared with a stationary engine.

At present the power distributed by the Niagara Falls Power Company might be divided into three classes:

1. The local service to electro-chemical and other industries within the city limits of Niagara Falls. This at present aggregates about 45,000 horse-power, divided among thirty industries. The largest users are the electro-chemical plants, which require current either for electrolysis or for the production of the very high temperatures obtainable in the electric furnace by which the reactions in their processes are brought about.

2. The Canadian service across the upper steel arch bridge to industries and electric railroads in Canada, reaching as far as St. Catherine's. This use is small at present, but it is the beginning of an industrial growth on the Canadian side of the river, which, in my opinion, will be very extensive in a few years. It now amounts to about 2,000 horse-power.

3. Long-distance service to Buffalo, Tonawanda, Lockport, and Olcott, which now amounts to a total of about 30,000 horse-power. In Buffalo approximately 24,000 horse-power is used, divided among a very large number of customers, making use of the power for all kinds of purposes. This includes the power for operating the Buffalo street cars and the electric lights in the city.

In Tonawanda about 4,000 horse-power is used for railway, lighting, and miscellaneous power purposes.

In Lockport the use amounts to about 1,500 horse-

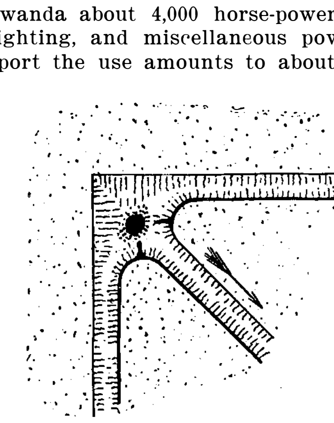


FIG. 15.—INJURIOUS THICKENING OF METAL, LIABLE TO PRODUCE A "DRAW" AND INCIPIENT FRACTURE.

power for railway and miscellaneous purposes. Five hundred horse-power is used at Olcott for operating one of the sub-stations of the International Railway Company. This station is 39 miles from the Falls, which is at present the longest distance to which Niagara power is transmitted. All the freight on the International Railroad, between Olcott and Tonawanda, is handled by Niagara power by means of electric locomotives.

It is hoped that this brief outline will give an idea

* Extract from a paper by H. W. Buck, Electrical Engineer of the Niagara Falls Power Co., read before the Engineers' Society of Western New York and published in the Journal of the Association of Engineering Societies.

of the present status of the Niagara Falls Power Company system. It represents, however, merely the beginning. In this country great cities have sprung up in certain localities for reasons far less important commercially than the conditions which exist on the Niagara frontier to-day. It is the center of population of the continent, approximately a focus of all the great trunk-line railroads, and unlimited cheap power for manufacturing is available. It is also the eastern terminus of the Great Lakes' commerce. This latter, if the Niagara River is deepened, will be extended almost to the brink of the Falls themselves, affording 20 miles of sheltered dock front.

The day will come when we shall see a steamless city, reaching unbroken from Buffalo to the Falls, the industrial triumph of Niagara's power.

[Concluded from SUPPLEMENT No. 1502, page 24068.]

COPERNICUS.*

By EDWARD S. HOLDEN, ScD., LL.D., Librarian of the U. S. Military Academy.

IN November, 1516, the quiet life of Copernicus at Frauenburg was broken up by his appointment as *Administrator bonorum communium* at Allenstein. The appointment was for one year, but the administration of Copernicus was so successful that he occupied the post during the years 1516-19 and again in 1520-21. His manifold duties in his place brought him again into conflict with the Teutonic knights. The interests of the order and of the church in Ermeland were totally antagonistic. At times open hostilities occurred and towns were besieged, taken and plundered. It is not necessary to follow this harassing strife into the details of Prussian and Polish politics. It is recounted in history as the *Fränkischer Reiterkrieg*. In 1521 Copernicus, then the recognized head of his chapter, was selected to draw up a statement of grievances against the order to be laid before the estates of Prussia. The lands of the chapter of Frauenburg had been overrun, the towns and villages plundered, the peasants had fled or had been killed. The castle of Allenstein, the residence of Copernicus, was itself in danger until it was saved by a four years' truce concluded at Thorn. In such stormy times astronomy was not to be thought of.

It was at this period that Copernicus composed, at the request of the Prussian estates, a memorial on the debasement of the coinage of the country and on the remedies to be adopted. "Money," he says, "is a measure, and like all measures it must be constant in value. What would one say to a yard or a pound whose values could be changed at the will of the measure-makers? The value of money depends not on the stamp it bears, but on the value of the fine metal it contains." Nothing could be clearer than this. His conclusions on the effects of a debased currency on the interests of landlord and tenant are not so sound. Copernicus also proposed to coin all the money of Prussia at a single mint, forbidding the towns to use their ancient privileges, which had been abused. This proposal, as well as others made in the years 1521-30, failed chiefly because Dantzig and other towns were not willing to relinquish vested rights. It is interesting to note that in his memorial of 1526 he sets the ratio of gold and silver as 1 to 12.

Bishop Fabian died in 1523. During the ensuing vacancy Copernicus was chosen administrator of the diocese. His duties were harassing. The troops of the order encroached more and more on the church holdings. The Lutheran heresy was also a source of anxiety. The steps taken by the administrator were marked by great tolerance. Before the preaching of the new faith was forbidden outright it was enjoined that it should be refuted by argument. A new bishop, Mauritius Ferber, was chosen in 1523, and a word must be said of the bishop's nephew and coadjutor, Tiedemann Giese. Born in 1480, he became canon of Frauenburg about 1504, and was the intimate and affectionate friend of Copernicus during the whole of his life. It was to him that Copernicus confided the manuscript of his great work in 1542. Bishop Ferber died in 1537, and Bishop Dantiscus of Culm was chosen in his place, while Giese by a compromise became bishop of Culm.

The last observation recorded by Copernicus in the "De Revolutionibus" is dated 1529. From this we may infer that his great work was essentially completed at that time, though it was repeatedly revised afterward. It had been begun twenty-three years earlier. It was not published until 1543, though its doctrines had been freely communicated to scholars and friends. In 1531 a set of strolling players, set on, it is said, by his enemies among the Teutonic knights and among the Lutherans, gave a little show at Elbing ridiculing the notion that the earth moved round the sun. The play was devised by a certain Dutchman who afterward became rector of the gymnasium at Elbing. That its satire was understood by the common people proves the opinions of Copernicus to have been fairly well known by his neighbors even at that epoch when absolutely nothing had been printed concerning them. About 1530 a manuscript commentary on the hypotheses of the celestial motions had been prepared by Copernicus for private circulation among men of science in advance of the publication of "De Revolutionibus." Two copies of this manuscript still exist, one at Vienna, one at Upsala. At the end of it a *résumé* of his new doctrine is given in seven axioms. (I.) There is only one center to the motions of the heavenly bodies; (II.) this is not the earth about which the moon moves, but (III.) it is the sun; (IV.) the sphere of the fixed stars is indefinitely more distant than the planets; (V.) the diurnal motion of the sun is a consequence of the earth's rotation; (VI.) the annual motion of the sun and (VII.) the motions of the planets are, primarily, not due to their proper motions.

In 1533 Copernicus was sixty years old and applied for a coadjutor. His duties were, at this time, made light for him. In 1532 an observation of Venus is recorded. Other observations were made in 1537. In 1533 he observed the comet of that year. It may be surmised (his memoir on the comet is not extant) that the retrograde motion of this heavenly body confirmed in his mind his criticisms of the system of Ptolemy.

The theory of Copernicus began to be known in Rome, and it was well received. In 1533 Widmanstad, secretary to Pope Clement VII., gave a formal explanation of the heliocentric theory of Copernicus to the pope and to an audience containing several cardinals and bishops. There is no doubt that the theory was received with interest. There is no sign of opposition, and Widmanstad subsequently obtained high honors in the church. The attitude of the Lutherans was, as we have seen, very different. The cardinal-bishop of Capua wrote in 1536 to Copernicus begging him for an explanation of his system.

In 1537 Dantiscus became bishop of Ermeland. All the canons of Frauenburg, Copernicus included, supported his nomination. Copernicus was known, however, to be a warm friend of Giese, who should have succeeded, as coadjutor, to his uncle's bishopric, but who was elected to that of Culm by a compromise. Difficulties soon arose between Copernicus and his new bishop, and the breach was widened in various ways. The bishop, himself a man of loose morals, ordered Copernicus to send away his housekeeper, on the assumption of illicit relations between the two, and kept the accusation alive by various official letters. Bishop Dantiscus oppressed Copernicus in various ways and remained his enemy in spite of certain advances on the part of the latter. If Copernicus ever feared the persecution of the church on account of his scientific teaching—of which there is little evidence—it was because his bishop stood ready to use every weapon against him.

Copernicus gained an ardent disciple in George Joachim of Rhaetia, known to us as Rheticus. He was born in 1514 and made his studies at Nuremberg under Schoner to such effect that he was appointed to be professor of mathematics at the University of Wittenberg in 1537, at the age of twenty-three. In May, 1539, he visited the great astronomer of Frauenburg chiefly to study his doctrines of trigonometry, and his trigonometric tables. Copernicus was then sixty-six years of age and his enthusiastic and loyal guest was twenty-five. He was received cordially and at once set himself to study the manuscripts of Copernicus. His visit extended itself from a few weeks to more than two years, and he became a firm believer in the new heliocentric astronomy, which he was well prepared to receive and to expound.

A letter from Rheticus, written a few months after his arrival at Frauenburg, affords one of the very few personal views of Copernicus that has come down to us. The letter was published with a long Latin title, in 1540, and is known as "Narratio Prima." "I beg you to have this opinion concerning that learned man, my preceptor: that he had been an ardent admirer and follower of Ptolemy; but when he was compelled by phenomena and demonstration, he thought he did well to aim at the same mark at which Ptolemy had aimed, though with a bow and shafts of very different material from his. We must recollect what Ptolemy has said: 'He who is to follow philosophy must be a freeman in mind.'" "My preceptor was very far from rejecting the opinions of ancient philosophers from love of novelty, and except for weighty reasons and irresistible facts. His years, his gravity of character, his excellent learning, his magnanimity and nobleness of spirit are very far from any such temper (of disrespect to the ancients.)" This letter, addressed by Rheticus to his old master Schoner, was the first easily accessible account of the new theory. The life-giving sun, he says, is placed in its appropriate place, and a single motion of the earth explains all the planetary motions. All is harmony as if they were bound together with a golden chain. He praises the great simplicity and reasonableness of the new doctrine, as well as the almost divine insight and the uncommon diligence of the master. He had formerly no idea, he says, of the immense labor required in such works, and the example of Copernicus leaves him in astonishment. Copernicus had made a complete collection of all known astronomical observations, and by these his theory was tested. The master was not content until every hypothesis had been fully proved.

Rheticus showed his admiration for Copernicus not only in these public, but also in private, ways. Books that he presented to the master (which are often annotated by Copernicus's own hand) are still to be found in various libraries of Sweden, where they were taken after the plundering of Ermeland in the thirty years' war. At Wittenberg Rheticus and his colleague Reinhold, Copernicans both, were by the conditions of their professorships obliged to teach the Ptolemaic system, just as Galileo, at Padua, a Copernican, had to confine himself to the exposition of Sacrobosco. It may safely be surmised, however, that their pupils did not leave them without hearing something of the true doctrines. In the "Narratio," Rheticus, who was a firm believer in astrology, uses the data of the "De Revolutionibus" as bases for wide-reaching astrological predictions. They are of no interest in themselves, but as the letter was written under the eye of Copernicus, they lead to the conclusion that they were not disapproved by the latter. So far as I know, this is the only evidence for the belief of Copernicus in astrology. We have no horoscopes from his hand but, like his contemporaries, he probably gave it a place among the sciences.

Rheticus deserves the gratitude of all calculators for his table of trigonometric functions (sines, tangents, secants) to ten decimal places, for every 10 sec. of the quadrant, published in a huge volume by his pupil, Otho, under the title "Opus Palatinum de Triangulis." The tables of Rheticus are the basis upon which Vlacq founded his great tables, and they have served as models for many followers. Lansberg's tables appeared fifteen years after the "Opus Palatinum" and lightened the immense labors of Kepler.

Toward the end of the year 1541 Rheticus returned to Wittenberg carrying with him a part of Copernicus's manuscript—a treatise on "Trigonometry"—which he printed in 1542. The complete manuscript of the "De Revolutionibus" was sent by Copernicus to his old friend Giese, the bishop of Culm, for such disposition as he thought best. The bishop sent it to Rheticus to arrange for its printing at Nuremberg, and to see it through the press. It fell out that the printing had to be confided to Andreas Osiander, a Lutheran minister interested in astronomy. The book was published early in 1543, and a copy reached Copernicus on May 24, the very day of his death.

Osiander prefixed to the volume an introductory note which he did not sign, as follows:

"Scholars will be surprised by the novelty of the hypothesis proposed in this book, which supposes the earth to be in motion about the sun, itself fixed. But if they will look closer they will see that the author is in no wise to be blamed. The aim of astronomy is to observe the heavenly bodies and to discover the laws of their motions; the veritable causes of the motions it is impossible to assign. It is consequently permissible to imagine causes, arbitrarily, under the sole condition that they should represent, geometrically, the state of the heavens, and it is not necessary that such hypotheses should be true, or even probable. It is sufficient that they should furnish positions that agree with observations. If astronomy admits principles, it is not for the purpose of affirming their truth, but to give a certain basis for calculation."

The best authorities affirm that Osiander's apology, which he had suggested to Copernicus as early as 1540, was unauthorized.

Osiander made many changes in the text also, and added the last two words of the title under which the book was printed—"De Revolutionibus Orbium Cœlestium." Readers of our day universally interpret the apology to be an attempt to forestall theological opposition and persecution. They remember the conflict of Galileo with the church. But Osiander was a protestant divine, Copernicus a Catholic priest. It is passing strange to conceive that a Lutheran schismatic should intervene to shield an orthodox Catholic from accusations of heresy. Moreover, Copernicus had good reasons for believing that the princes of the church would receive his work favorably. His doctrine had been known to them since 1530. He knew, however, that several powerful university teachers—Fracastor for one—opposed it. Ought we not to interpret the apology as an address to men of science? Whewell justly remarks that Copernicus seems to consider the opposition of divines as a "less formidable danger" than that of astronomers. It is difficult to admit that Osiander dared to prefix this note without the authorization of Copernicus, or, at least, of Rheticus. There seems to be no reason to doubt that it was addressed solely to men of science.

The words of the apology represent the exact point of view of the ancients, and are entirely opposed to the attitude of modern science. Centuries of experience have taught the modern world that there is one and only one solution to a scientific problem. Modern science is a search for such unique solutions. Anything less definite is an hypothesis to be held tentatively and temporarily, it may be even alternatively with another, or others. The theories of the Greek philosophers were, in general, held by them primarily as hypotheses. Their whole attitude toward scientific certainty was thus entirely different from our own. In the time of Copernicus the minds of most men were cast in the ancient temper. It is, in fact, from his century that the new insight dates. This is not to say that colossal geniuses like Archimedes or Roger Bacon did not work in what we call the modern spirit. It is simply to confirm that most of the contemporaries of Copernicus belonged, in this respect, to the ancient world. The apology expressed exactly their attitude. The attitude and temper of the modern world are entirely different; they are perfectly formulated in these words of Pascal: "Ce n'est pas le décret de Rome sur le mouvement de la terre qui prouvera qu'elle demeure en repos; et, si l'on avait des observations constantes qui prouvassent que c'est elle qui tourne, tous les hommes ensembles ne l'empêcheraient pas de tourner, et ne s'empêcheraient pas de tourner avec elle."

It required this very book of Copernicus to suggest the pregnant phrase of Pascal.

In the letter of dedication to the Pope—Paul III.—

* From Popular Science Monthly.

Copernicus speaks in his own name. His words are simple and serious, full of dignity and conviction:

"I dedicate my book to your Holiness in order that both learned men and the ignorant may see that I do not shrink from judgment and examination. If perchance there be vain babblers who, knowing nothing of mathematics, yet assume the right of judging on account of some place of Scripture perversely twisted to their purpose, and who blame and attack my undertaking, I heed them not and look upon their judgments as rash and contemptible."

He is here referring to divines. The following is addressed to astronomers:

"Though I know that the thoughts of a philosopher do not depend on the judgment of the multitude, his study being to seek out truth in all things so far as is permitted by God to human reason, yet when I consider how absurd my doctrine would appear I long hesitated whether I should publish my book, or whether it were not better to follow the example of the Pythagoreans and others who delivered their doctrine only by tradition, and to friends."

The doctrine of Copernicus was first formally judged by the Roman Church in 1615 when Galileo was before the Inquisition in Rome. The judgment was in these terms:

"The first proposition, that the sun is the center and does not revolve about the earth, is foolish, absurd, false in theology, and heretical, because expressly contrary to Holy Scripture.

"The second proposition, that the earth revolves about the sun and is not the center, is absurd, false in philosophy and, from a theological point of view at least, opposed to the true faith."

In the year 1616 the works of Copernicus were placed upon the Index "until they should be corrected," and "all writings which affirm the motion of the Earth" were condemned at the same time. The congregation issued a notice to its readers in 1620, thus conceived:

"Although the writings of Copernicus, the illustrious astronomer, on the revolutions of the world have been declared completely condemnable by the Fathers of the Sacred Congregation of the Index, for the reason that he is not content to announce hypothetically certain principles concerning the situation and motion of the earth, which principles are entirely contrary to the sacred Scripture, and to its true and Catholic interpretation (which can absolutely not be tolerated in a Christian man) but dares to present them as indeed true; nevertheless, because this book contains things very useful to the republic, it has been unanimously agreed that the works of Copernicus ought to be authorized, so far printed, as they previously have been authorized, correcting, however, according to the following notes, the passages in which he does not express himself hypothetically, but affirmatatively maintains the motion of the earth; but those which, in future, will be printed must not be so printed save with the following corrections, which are to be placed before the preface of Copernicus."

The corrections follow; they are not numerous or important.

The works of Copernicus were still on the Index in the year 1819. In the following year Pope Pius VII. approved a decree of the Congregation of the Holy Office that the Copernican system, as established, might be taught, and in 1822 "the printing and publication of works treating of the motion of the earth and the stability of the sun, in accordance with the general opinion of modern astronomers, is permitted at Rome." Centuries before this date the real question had been judged; but its formal settlement in the Roman Church was postponed to our own day.

The judgments of the Congregation of the Index upon the heliocentric theory were an incident in the history of the relations of Galileo with the authorities at Rome, and they can best be understood in connection with that history. Something, however, may be said of them here. It is to be observed that the first proposition is condemned because it is contrary to scripture, heretical, false in theology, *absurd* and *foolish;* and the second because, from a theological point of view it is opposed to the true faith, *false in philosophy* and *absurd.* The words not in italics relate to judgments upon points of doctrine. The words in italics relate to judgments upon matters of philosophy or of science.

It was entirely competent for the Congregation of the Index to render decisions upon matters of theology which were binding upon all Catholics. The committee was organized and existed for that purpose. Every institution, religious or secular, must decide for itself on matters of the sort. Not to do so is sheer suicide. The competence of the Roman Church and of the Congregation of the Index to decide *for itself* questions of what is opposed to its faith, contrary to Scripture, false in theology, is not to be denied. This was a conflict of theology with an alleged heresy. Copernicus was a member of the Roman Church. The soundness of his theological opinion was a matter for doctors of theology to settle in their own church in their own way. They did not decide it, however, until they had taken the advice of astronomers who pronounced the heliocentric theory to be baseless. (Delambre, "Astronomie Moderne," i., p. 681.) Tycho Brahé, also—a great authority—had declared it to be "absurd and contrary to the Scriptures." These two points are often forgotten by writers of the Martyr-of-Science School.

On the other hand, no one can admit for a moment the right or the competence of the Congregation or of the Church to pronounce final judgment upon a question of philosophy or of science. The whole world is now agreed that it is an impertinence for a body of theologians to pronounce upon a question of science, precisely as it would be for a congress of scientific men to pronounce upon a point of theology.

The reasons that led the Congregation of the Index to take this fatal step must be considered in connection with the history of Galileo. It will not be out of place here, however, to attempt to understand the mistaken point of view of the churchmen responsible for the decision.

For fourteen hundred years the theory of Ptolemy had ruled. In 1543 Copernicus proposed a new and revolutionary system. In its essential point the system was true, as we know now; we also know that it was false in asserting that the planets moved in circular orbits (they really move in ellipses), in accepting trepidation as an incident to precession, and in other matters of the sort. It even asserted, falsely, that the center of the orbit of the earth and not the sun was the center of planetary motion, so that in a strict sense it was not even a heliocentric theory. The theory of Copernicus was not *proved* to be true, in its essential feature, until Galileo discovered the phases of Venus, in 1610. Is it any wonder that doctors of the church five years afterward were not convinced? They were profoundly ignorant of science and not in the least interested in science as such. Any one of them could recollect that Tycho Brahé, the greatest astronomer of his time, had in 1587 made a theory of the world which placed the earth at its center. He then did not agree with the theory of Copernicus. He expressly rejected it. It could easily be recollected, also, that in 1597 Kepler had proposed his first theory of the world, in which the planets were arranged according to fanciful and false analogies with the shapes of the five regular solids of Plato. It is now known that the systems of Tycho and of Kepler were both false. Ought the church doctors to have accepted them when they were proposed? In 1609 Kepler proposed a second theory of the world based on elliptic and heliocentric motion. How could the doctors know that this second system was the true one, as indeed it was? Kepler was still alive. How could they know that he would not propose a third theory? They had seen the doctrine of Ptolemy denied by Copernicus; the doctrine of Copernicus denied by Tycho; the doctrine of Tycho denied by Kepler's first system; the doctrine of Kepler's first replaced by that of his second system. All this had occurred within their own memories. In scientific theories as such they had no interest whatever; they were solely concerned for religion. Is it surprising that they did not promptly accept a theory which they did not understand?

It was, however, a profound and inexcusable error for them to condemn it; and by so doing they, unwittingly, dealt a heavy blow to the church. For once, theology engaged in a warfare with science; and the issue was an overwhelming and deserved victory for science. There have not been many such conflicts. Very exceptional conditions are required to bring them about, as may be seen in the long history of Galileo.

It is very difficult to form a vivid conception of the whole character of Copernicus either from his works or from his portraits. We know far too little of his history and too little of the time in which he lived. I have found no summary in any of his biographies that can be called satisfying and I have never been able to make one for myself. I venture to reprint that of Bertrand, and to inclose in parentheses those parts that we positively know to need modification or correction.

"Capernic est pour nous tout entier dans son livre. Sa vie intime est mal connu. Ce qu'on en sait donne l'idée d'un homme ferme, mais prudent, et d'un caractère parfaitement droit; tout entier à ses spéculations et comme recueili en lui-même; il aimait la paix, la solitude, et le silence. Simplement et sincerement pieux, il ne comprit jamais que la verité pût mettre la foi en péril, et se réserva toujours le droit de la chercher et d'y croire. Aucune passion ne troubla sa vie (ou ne lui connaît même pas de commerce affectueux et intime*); ennemi des discours inutiles, il ne rechercha ni les éloges ni le bruit de la gloire; indépendant sans orgueil, content de son sort et content de lui-même, il fut grand sans éclat, et, ne se révélant qu'a petit nombre de disciples choisis, il a accompli une revolution dans la science (sans que, se son vivant, l'Europe en ait rein su)."†

The system of Copernicus belongs to him alone. It is not the system of Philolaus or of Aristarchus . . . but his own. His name is justly attached to it on account of the care with which he explained its every part, brought out all its phenomena, discovered the causes of these precessional movements which had been known for eighteen hundred years, and explained only by the hypothetical existence of an eighth sphere which made a revolution in 36,000 years around the axis of the ecliptic, while, at the same time, it was constrained to turn daily about the axis of the equator to account for the rising and setting of the stars. It is then Copernicus who really introduced the motion of the earth into astronomy, not merely into academic disputations; it is he who demonstrated how the revolution of the earth about the sun explained the succession of the seasons and the precession of the equinoxes; it is he who showed how simply the retrogradations of the planets are explained by the unequal velocity with which they traverse their concentric orbits about the sun; it is he who put astronomy on new foundations and who opened the way for all later researches. It is to Kepler's enthusiasm over the new truths that we owe the discovery of the true shape of the planetary orbits, and the laws of their motion. The idea of the motion of the earth was unfruitful among the ancients because it was never entertained with seriousness. Its adoption by Copernicus is the beginning of modern astronomy. (Delambre.)

The mountain peaks that cluster closely round the Lick Observatory in California are of different heights and were unnamed when the corps of observing astronomers took possession of the newly established station. Names were assigned to them in the order of their heights—Copernicus, Galileo, Kepler, Tycho, and Ptolemy. One of the staff of observers, who greatly distinguished himself during his short career at the observatory, objected to the assignment of the name of Copernicus to the highest peak. Copernicus was, no doubt, a great astronomer, he said, but was he pre-eminent? Should not the highest peak have been assigned to another? The objection is answered the moment the relation of Copernicus to the whole thought of the world is comprehended. His skill as a mere observer, his power as a mere geometer, is not in question. His place is not to be assigned by narrow criteria like these. What was the attitude of man toward everything not himself before the day of Copernicus? toward things divine, things spiritual, things natural? What is his view of the world now? The changes are so fundamental, extensive and bewildering as not to be described, much less estimated, except by a long series of separate steps, each one opening new worlds in religion, philosophy, science, art, technics. To name them all would be to summarize the entire history of human progress for three hundred and fifty years. In the long stairway of ascent Copernicus established the foundation stone. Tycho, Kepler, Galileo, Newton, Kant, Laplace, Herschel, Darwin (to speak only of men of science) each laid successive steps upon it. Until the first was firmly laid no building, no advance was possible. We stand to-day in a high place of vantage won for us by the master builders of more than three centuries. Without Copernicus their work would have been in vain. The modern world is erected upon foundations that he laid.

* His relations with his uncle and with Giese were both affectionate and intimate; those with the young Rheticus were ideal, considering their ages.

† From the year 1514 onward his name was widely known among the circles of the learned, and his theories were circulated as early as 1530.

NEW METHOD OF MANUFACTURING STEEL.

It is reported that successful experiments have just been made by the Iron, Steel and Metals Manufacturing Company at Melbourne, Victoria, for the purpose of proving the value of certain patent rights for the direct production of wrought iron and steel without first producing pig iron. Only a rough idea of the process may at present be had, though trial runs with New Zealand magnetic iron sand are now being made on a somewhat larger scale than hitherto. The sand is first separated from its gangue by electromagnetic separators, this treatment leaving a pure magnetic iron oxide. The sand is then fed from a bin into the furnace, which is entirely novel in its features, being chiefly mechanical and automatic in its operation.

The ore drops from the bin into a slowly revolving cylinder placed at such an angle that the ore travels forward continuously in it. As it does so it is heated to a dull red by the waste gases from subsequent operations. From this cylinder the ore drops into a second revolving cylinder, where the fine particles are subjected to the action of reducing gases which reduce the magnetic oxide of iron to the metallic form, at the same time permitting the particles to retain their individuality. From this second cylinder the reduced ore drops into a smelting bath at the bottom of the revolving cylinders, and the molten steel or malleable iron as the case may be is tapped from this whenever that operation is necessary. It will thus be realized that the process is one of great simplicity and yet of much ingenuity. Not the least interesting part of it is the use of fuel oil for heating purposes. This is employed to secure concentration of heat and direct application in the furnace work. It is found that the fuel oil possesses many advantages over producer gas as used in existing smelting practice. The work done so far has demonstrated that not only is oil a cheap fuel, quite irrespective of the capital outlay that would be required if it was decided to utilize producer gas, but it is so thoroughly under control as to insure the best service.

The temperature at which iron ore melts is given variously at from 1,500 deg. to 2,000 deg. Cent., according to its purity. The accurate gaging of temperature in the furnaces plays a very important part in the company's work, and accordingly an installation of thermo-electric thermometers has been made at the company's works. The apparatus consists of a "couple" consisting of a platinum-iridium junction inclosed in a metal tube fully 3 feet long, which is placed in the center of the furnace, and the temperature is then recorded on the dial of a special form of voltmeter, each division on which represents 25 deg. Cent. This voltmeter reads up to 1,600 deg. and is placed at any convenient distance from the furnaces.

The various thermometers are connected with a switchboard, which is again connected with the "couples" or tubes in the furnace. In the installa-

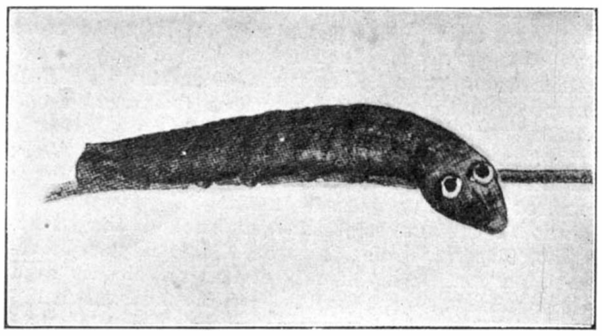
tion under notice four "couples" will be used, inserted in different parts of the furnace, and separately connected with the board, so that the reading of any thermometer can be taken, and any discrepancy in the heat of different points of the furnace can be quickly remedied. It is interesting to notice that the voltmeter is so extremely sensitive that variations of heat down to 0.5 deg. were easily noticeable in the trial test. The greatest temperature recorded was 1,300 deg. Cent., equal to 2,340 deg. Fahr.—John P. Bray, Consul-General.

TERRIFYING MASKS AND WARNING LIVERIES.*

By Percy Collins.

It has been suggested—and the theory has received to some extent the support of experimental proof—that certain kinds of insects derive protection from the grotesqueness or hideousness of their appearance. An oft-cited example is the very remarkable-looking caterpillar of *Stauropus fagi*, the lobster moth. This insect was at one time considered a great rarity in England, and as such was much prized by collectors. Of recent years, however, it has been found in considerable numbers in the beech woods of the Upper Thames Valley, and entomologists have had ample opportunity to examine its appearance and habits in the wild state.

Prof. Poulton describes the resting caterpillar as possessing a considerable resemblance to a withered leaf irregularly curled up—the likeness being gained by the combined effect of the creature's color, its



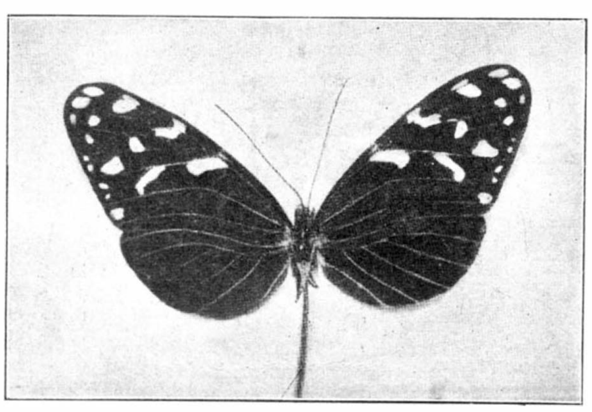
Larva of *Chaerocampa porcellus*, in Terrifying Attitude (Drawn from Life).

curiously modified legs, and the manner in which these are arranged.

It is clear, therefore, that this remarkable larva is concealed from its enemies by a protective likeness to its habitual surroundings. But it has yet another means of defense at its disposal. Should it be disturbed by a rustling of the leaves and twigs in its immediate neighborhood, and become convinced that its disguise has been penetrated, it immediately assumes what has been called its "terrifying attitude."

In this position it is described as looking very like a large spider, but with all the characteristic points in a spider's appearance greatly exaggerated for the sake of effect. The legs and body are, for the time being, arranged in such a manner that the creature seems changed from a harmless caterpillar into something strangely disquieting to look upon.

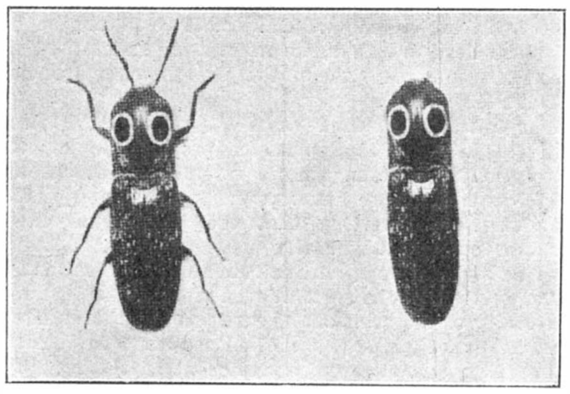
In thus mimicking the attitude and appearance of an exaggerated spider, the lobster moth caterpillar is really trading upon the reputation of a well-recognized noxious creature; and the defense has been shown by experiment to be of no little avail against the attacks of birds and other insect-eating creatures, which exhibit varying degrees of alarm and disgust at sight of the caterpillar in its terrifying attitude. But, as several observers have pointed out, it is more than likely that the spider-like appearance exists mainly as a special safeguard against the insect enemies of *Stauropus fagi*. In common with the larvæ of most lepidopterous insects, this caterpillar is liable to the attacks of ichneumon flies, which deposit their eggs upon or beneath its skin. In the majority of instances such "stung" larvæ die miserably ere they are



Melinea mesatis. Ex Colombia, S.A. (Red, Brown; Anterior Areas of Forewings Black, Spotted White).

able to assume the imago state; and it is only reasonable to assume that any trick or device calculated to scare away these insect foes would directly benefit the species by enabling a greater number of its caterpillars to arrive at maturity. And as a large and presumably ferocious spider is a vision of dread to all the lesser denizens of the insect world, the lobster moth caterpillar's terrifying mask is probably very effective.

Similar instances of what looks like trading upon the reputation of some well-known noxious creature occur among insects, and in some instances the prototype seems to belong to some widely different group

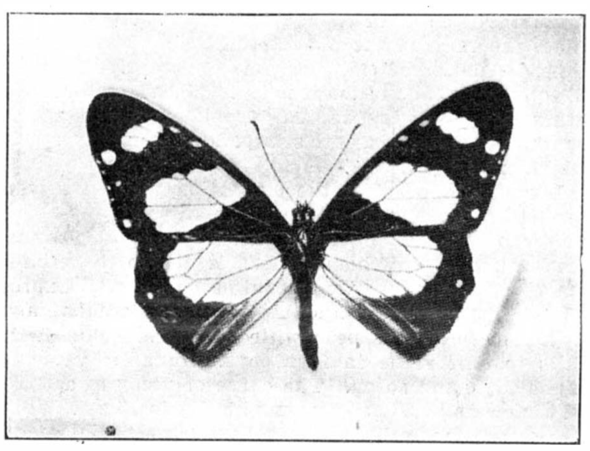


Alaus sp. Central America. As it Appears when Running; and when, under the Stimulus of Alarm, it has Drawn its Legs and Antennæ Beneath its Body.

of living creatures. Thus, a South American caterpillar mentioned by Mr. Bates startled everyone to whom it was shown by its snake-like appearance; while among our native species the larvæ of the two elephant hawk moths (*Chaerocampa elpenor* and *C. porcellus*) are striking instances of a protection gained in a similar manner.

Like the caterpillars of the lobster moth, those of the elephant hawks are difficult to detect when they are at home among the leaves of their food plants, owing to their brown—or more rarely green—coloring. But when actually discovered, or when thoroughly alarmed by the rustling of the leaves, the caterpillar draws back its head and the first three segments of its body into the fourth and fifth segments. What then happens is well described by Prof. Poulton. "These two rings (the fourth and fifth segments) are thus swollen, and look like the head of an animal upon which four enormous, terrible-looking eyes are prominent. The effect is greatly heightened by the suddenness of the transformation, which endows an innocent-looking animal with a terrifying and serpent-like appearance."

This description applies to the *C. elpenor*. In the case of *C. porcellus* the eye spots on the fifth segment, though present, are comparatively inconspicuous. It is a curious fact that these strange markings do not attract particular attention when the caterpillars are



Methoma themisto. Ex Rio Granda (Black with "Clear" Areas).

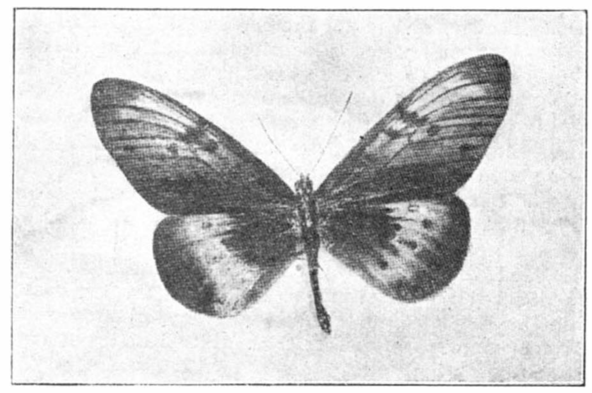
quietly at rest or feeding. As soon, however, as they assume their terrifying mask, under the stimulus of apprehended danger, the staring "eyes"—owing to the swelling of the segments as the head and first three body rings are withdrawn—become enormous and prominent. All field entomologists who are familiar with these caterpillars in the wild state are willing to bear testimony to their startling appearance when they have assumed their terrifying attitude.

Very similar eye spots, probably of a like protective value, are seen upon the thoraces of certain Central American beetles of the genus *Alaus*. As in this case the markings are delineated upon the hard surface of the thorax they are not really more marked at one time than another. Yet their terrifying appearance is enhanced considerably when the beetle assumes the attitude with which it responds to indications of approaching danger. In common with most species of the great "click-beetle" group (*Elateridæ*) to which the genus *Alaus* belongs, these insects are capable of folding their legs and antennæ so closely beneath the body that they are completely hidden, and of remaining perfectly quiescent in this attitude for a long period of time. A glance at the accompanying photograph will give the reader some idea of the weird appearance of an *Alaus* beetle under these conditions, It cannot be said to resemble any other living creature, noxious or innoxious. Yet its appearance is sufficiently forbidding to discourage hostile attack.

In dealing with the first part of our title we have briefly discussed several insects which are able, at will, to masquerade as something terrible and alarming. They can put on, as it were, terrifying masks, and scare away their would-be persecutors. But the protection thus gained is the outcome of bare-faced bluff, and it is conceivable that the enemy may one day discover and profit by this fact. Warning liveries, on the other hand, are anything but meaningless bluster. They indicate that the creatures distinguished by them possess certain noxious characteristics which render them unwholesome or unpalatable.

At the present day, students of entomology accord a fairly general acceptance to the theory of warning coloration as explaining certain extremely striking colors and color contrasts which occur throughout the insect world. In cases of protective coloring, the insects resemble more or less closely those objects by which they are habitually surrounded—the protection becoming more certain in proportion to the completeness of the likeness. But with warning colors, exactly the reverse is the case. Insects assignable to this class are not colored to be hidden, but in order that they may readily be seen.

It is believed—and in many instances this is definitely known to be the case—that such conspicuously colored insects possess some hurtful quality which renders them inedible, and that their showy livery acts as a warning to insectivorous creatures in general. The reason why warning colors are thought to benefit a species is explained in the following manner: Insects are, for the most part, very frail creatures, and one peck from a bird bent upon testing the edibility of (say) a caterpillar, would, in all probability, result in the creature's death. Thus, the mere fact of

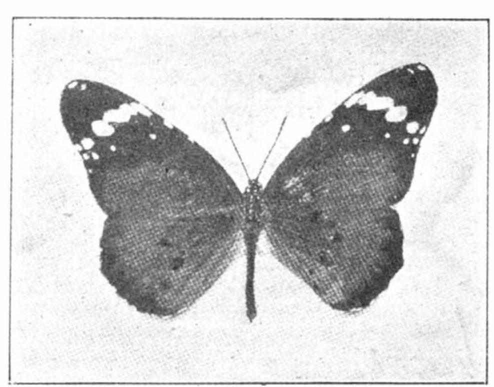


Acraea sp. Ex Sierra Leone (Fore Wings Sooty, Black Spots; Hind Wings Brick Red, Black Spots).

its being unsuitable for food would be of no avail in saving its life. But if the caterpillar were colored in a manner sufficiently striking to become impressed upon the mind of the bird, a distinct advantage to the species might be expected to result. For the bird, presuming it to be capable of learning a lesson, would give up "experimental tasting" in so far as insects colored in a similar manner were concerned.

As an example of a warning color combination by no means uncommon in the insect world, the caterpillar of the Cinabar moth (*Euchelia jacobææ*) which is zebra-striped in alternate bands of black and yellow, may be cited. This larva has been proved to be nauseous in taste, and to be rarely eaten by birds or other insectivorous creatures old enough to have gained experience in "the ways of the world." The same yellow and black striping is to be seen upon the bodies of many species of wasps and bees—insects which would prove very unsatisfactory eating on account of their poisonous stings.

The theory of warning coloration was first suggested by Dr. A. R. Wallace to account for the extremely bright colors exhibited by certain caterpillars. It has since been applied to whole tribes of insects, of all orders; and so strong is the evidence in its favor—the result of systematic experiments conducted in various latitudes with birds, lizards, and other insect-eating creatures—that what was originally a theory may now fairly be regarded as a well-established fact. Indeed, so distinct are the colors and color combinations possessed by inedible species, and so unlike are they to the colors of insects which do not possess noxious qualities, that the student is frequently able to tell at



Danais Chrysippus. Widely Distributed in Eastern Hemisphere (Fulvous-Brown, Marked with Black and White).

a glance whether a given species is an example of warning coloration or not, even though he may never before have seen it.

Among butterflies, the examples of warning liveries are particularly striking.

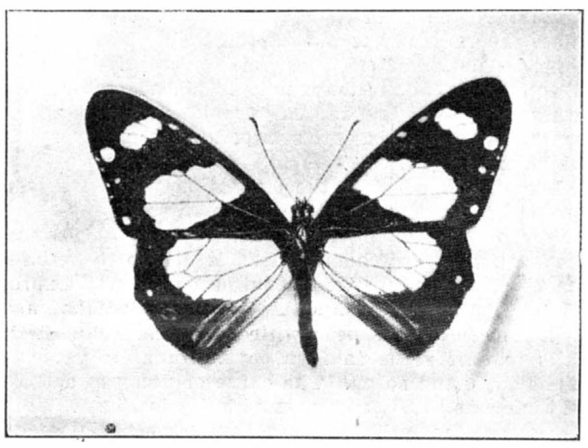
In South America, the "protected" species—as those which possess some noxious quality are usually termed

*From Knowledge and Scientific News.

—are exceedingly numerous, and are well typified by such genera as *Methoma*, *Melinea*, and *Heliconius*. These butterflies are rendered inedible by the acrid or evil-smelling juices contained in their bodies. Even in the case of long-dead specimens which have been temporarily relaxed for setting, the unpleasant odor of these juices is very apparent, resembling the scent which is left upon the fingers after handling a ladybird beetle. Such butterflies, in common with other evil-tasting species in other parts of the world, are slow and measured in their flight, fluttering in an unconcerned manner from flower to flower as though experience had taught them that they have little to fear from birds, reptiles, monkeys, and other enemies of insect life.

Although the species of warningly colored butterflies are exceedingly numerous in the New World, they are by no means unrepresented in other parts of the globe. In Africa, the genera *Acraea* and *Amauris* have a wide range, and are represented by many well-marked species. While in the Indo-Malayan region the great sub-family of the *Danainae*, all the members of which are rendered conspicuous by their warning liveries, is a dominant group.

The accompanying photographs represent a few common and very typical warningly-colored butterflies, and a glance at them will give the reader a better idea of the special designs associated with inedibility than could be gained from a mere description. It will be seen that the aim is to produce a startling effect; one, moreover, that will not easily be overlooked or confused. On contrasting such warning liveries with the tints of insects which are wholly or partially protectively colored to harmonize with their surroundings, it becomes very obvious that designs so different must have been produced in response to equally diverse circumstances. It is, moreover, worthy of note that warningly-colored butterflies, as a rule, differ little in the tinting of the upper and under surfaces of their wings; whereas butterflies unprotected by inedible qualities,



Amauris ochlea. Ex South Africa (Blackish-brown, with White Areas).

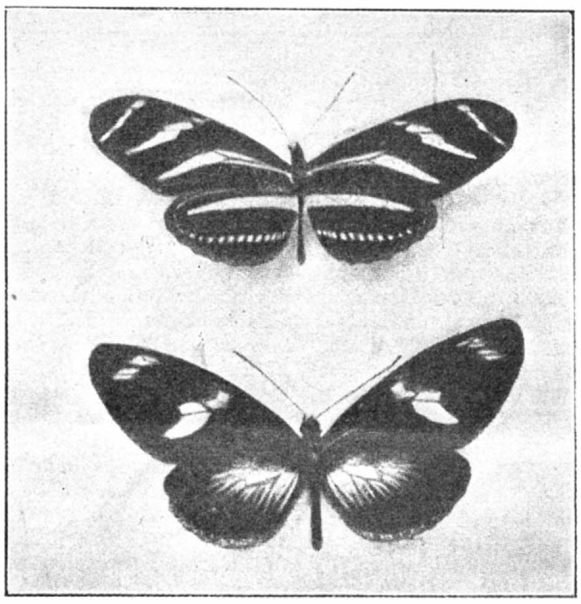
even though they may possess brightly-colored upper surfaces to their wings, usually have them tinted beneath in harmony with leaves, bark, sand, or rock. Thus, as soon as they settle with folded wings, their protective coloring comes into play.

OPHIR, THE LAND OF KING SOLOMON'S MINES.

"And King Solomon made a navy of ships in Eziongeber, which is beside Eloth on the shore of the Red Sea in the land of Edom. And Hiram sent in the navy his servants, shipmen that had knowledge of the sea, with the servants of Solomon. And they came to Ophir and fetched from thence, four hundred and twenty

Larva of *Chaerocampa elpenor*, Showing "Eye Spots" on Fourth and Fifth Segments of Body.

talents and brought it to King Solomon." (I. Kings ix. 26-28.) This is the succinct description of the source of Solomon's wealth in the precious metal. It is about all we have of a strictly trustworthy nature concerning that earlier argosy, the discovery of whose destination has baffled the investigating minds for nigh unto thirty centuries. Such in fact is the account given in the first book of Kings of the early voyage of the Israelites in search of the Golden Fleece one thousand years before the birth of Christ. Successful it was beyond peradventure, for a kikkar (talent) in



1. *Heliconia charithonia.* 2. *Heliconia quirina* Ex Trop. South America The Heliconiidæ Have all Dark Brown or Black Wings, Lined or Spotted with Very Brilliant Colors.

the time of Solomon weighed 95.2 pounds. From this we may reckon the value of the gold brought in by the fleet to have been about $8,500,000 in the money of to-day. This expedition was not the only one of its kind, for if we turn to the next chapter of the same book of Kings, verses 21 and 22, we find: "And all King Solomon's drinking vessels were of gold, and all the vessels of the house of the forest of Lebanon were of pure gold; none were of silver: it was nothing accounted of in the days of Solomon. For the King had at sea a navy of Tharshish with the navy of Hiram; once in three years came the navy of Tharshish, bringing gold and silver, ivory, and apes and peacocks."

The land of Ophir, so rich in gold, with which the Israelites were so well acquainted, vanished later from the knowledge of the civilized nations; it became indeed a land of fable, of the confines of which even the most acute explorers and investigators could find no further trace. Speculation placed it now in Arabia and again in India; four hundred years ago Columbus believed he had located it again, and this time in the new world which he gave to plodding millions of the old. When in years later the adventurous Portuguese in their voyages to the Indies, tore from the grasp of the Arabs the eastern coast of Africa, they rejoiced in the belief that Ophir was again found in the country lying back of Sofala. Among other things, Conto, a Portuguese writer of the seventeenth century, delivers himself thus concerning the gold mines of Zambesia: "The richest of all the mines are those of Massapa, where the Arabs point out one as the Abyssinian mine from which the Queen of Sheba took the greater part of the gold which she gave Solomon for the Temple. And this is indeed Ophir, for the Kaffirs call it *Fur*, and the Arabs *Afur*." But the declaration of the Portuguese was not susceptible of proof, and the momentous question of Ophir remained still unsettled.

In the year 1876 the German African traveler, Carl Mäuch, made an important discovery in Mashonaland, south of the Zambesi River. Three hundred kilometers west of Sofala he came upon the extensive ruins of Zimbabye, which were later explored by others, particularly by an Englishman, J. T. Bent, who went over them with characteristic thoroughness. It now became clear that those walls and towers of cyclopean masonry might no longer be considered the work of native African tribes; every circumstance seemed to point to the conclusion that in these ruins we have the remnants of an ancient settlement of a Phenician people, and many discoveries proved further that those strangers in the land, in the hoary ages of long ago, actually exploited the gold deposits in the most approved fashion.

In one of his charming and attractive articles upon "The Dark Realms of Human History," Dr. P. Schellhas presented several years ago a most glowing account of the status of exploration at the time. The riddle of Zimbabye had not then been solved. In the interim, immediately after the discovery of gold in the Transvaal, the region has been more completely explored. On every side were to be met similar ruins or old mines, sunken 600, 900, and even 4,000 feet into the bowels of the earth, from which surely millions of tons of ore must have been carried to the surface. In their book, "The Ancient Ruins of Rhodesia," Hall and Neal estimate the number of these diggings at 75,000, and select the figure 500 as being nearest to the number of ruined cities, fortresses, and temples. There is no strip of the earth's surface that can show anything like it; there can be no doubt but this very region was the Eldorado of antiquity, from which the ancient peoples drew their supplies of the noble metals.

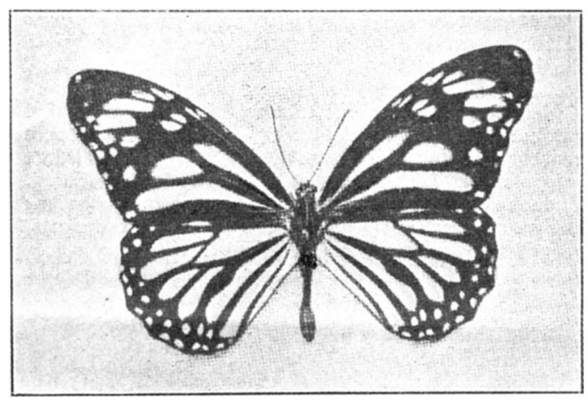
But of recent years a newer and clearer light has been thrown upon those gold diggers long, long since gathered to their fathers and buried in the oblivion of the ages. Dr. C. Peters has, within a very few years, traveled, with scrutinizing gaze and painstaking industry, over the region between the Zambesi and the Sabi, devoting himself to the sole purpose of solving the question concerning Ophir. After his return, his efforts were materially supplemented by the well-known Arabian explorer, Dr. E. Glaser, to such an extent, in fact, that the old Ophir conundrum has been answered at least with regard to its chief points.

The results of his tireless investigations are furnished to us by Dr. C. Peters, in his highly interesting work, "Ophir, the Gold-land of Antiquity." How shall we be best able to conceive of the state of things at that early date? Let us endeavor to picture how the world appeared in the neighborhood of the Indian Ocean about 1,000 years before Christ. What was the nature of the political circuit into which the fleets of Solomon and Hiram entered when they passed through the Straits of Bab-el-Mandeb?

During a period, placed as near as may be at about 3,000 years before the birth of Christ, important changes of position occurred among the nations dwelling in the vicinity of the Indian Ocean. The Aryan tribes, till then living in eastern Iran, broke up their habitations and descended in hordes upon India, where they appeared first as conquerors in the valley of the Indus, and subsequently upon the banks of the Ganges.

At about the same time there occurred also a second pouring out of the Semitic tribes, streaming forth from the region about the Persian Gulf.

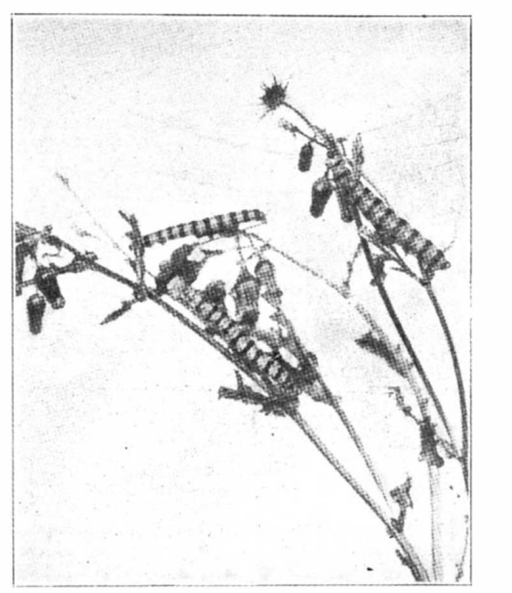
In this region all accounts place the first home of the Punic nations, the Phenicians of antiquity, and from here they flowed out in two mighty and irresistible streams to the north and to the south. The living wave which rushed onward toward the north burst over the feeble obstructions offered by the Red Sea into the Mediterranean district, where they began to establish their settlements on shore and islands 2,000 years before Christ. To these belonged the Phenicians of Asia Minor, the Hebrews, the Aramæans, and further the Carthaginians, while their most recent off-



Danais edmondi. Ex Philippines (White and Black).

shoots reached the British Isles under the name of Milesians. The second great branch of the Phenician flood founded empires in Southern Arabia. To them belonged the Himyarites, Sabæans, Minæans, Ausonians, Catabanians, and Abyssinians. From the mainland of Arabia they managed to subject and control the east coast of Africa as far south as Sofala.

During Solomon's reign the realm of the Queen of Sheba extended northerly and touched the southernmost province of Solomon's empire. The East African colonies of these Sabæans were very likely their most southern possessions; and their central point seems to have been the Sabi River and its "hinterland," where we still find many names that remind us to-day of the epoch when the Queen of Sheba and her minions



Larvæ of *Euchelia jacobœæ.*

ruled the land. (Such names occur as *Rusapi*, the many instances of *Massapa*, *Umsapa*, etc.)

And now the question: Whither then in the world did the fleets of Solomon turn their prows in search of the precious gold?

Was Southern Arabia their goal? Hardly; for to advance into Arabia, an essentially territorial prince

such as Solomon then was, did not require the building of a navy; the overland route lay almost uncontested before him. Moreover, arrived in Arabia, the Jews must needs have obtained the great stores of gold through the medium of trade, a *quid pro quo*; and it is scarcely conceivable what the nature of the wares might be which they would give in exchange. They were truly an agricultural race. Nor was any gold to be sought in India. No very rich gold mines were known to exist there. As for the people themselves, they were purely pastoral.

Only East Africa then could have been their destination. The friendly relations between King Solomon and the Sheban Queen lend much color to the probability that she gave him permission to sail to her colony and there dig for gold. As we should say in the parlance of to-day, she gave him a mining concession. This explains without extraordinary effort how it was that the ships returned every three years, laden with a cargo of gold worth millions of dollars. Of the other wares stowed in the hold, both the ivory and the apes could have been obtained in Africa, and in the regions not far removed from the mines. Of silver and pea-fowl, of course there were none, but these might easily have been purchased in the Arabian ports at which they touched on their homeward way.

It is to be regretted that the name Ophir is not yet satisfactorily explained. In more recent times the Arabs were acquainted with a region somewhat south of the Zambesi, known as Afur, and a mountain appears on old Portuguese maps as Fura. It was in this vicinity that Dr. C. Peters first applied his exploring faculties. Here he came into the land of the Makalanga, whose headman dwelt in Inja-Ka-fura, i. e., the place of the great Fura. Here he became acquainted with the religious conceptions of the natives, and found them to be exceedingly peculiar.

The Makalanga believe in a great and mighty god, the *Meregu*, who lives above in the blue heavens. Besides him, there is a god who dwells upon the earth or somewhere within it whom they serve. This is a smaller and less powerful god, standing much nearer to man in all his relations; him they call Kabulu-Kagoro. To him belongs all the fire in the land, and his service is superintended by the high priestess of the tribe, an old woman, who bears the honorable and exalted title *Quaraquate*. She is supposed to be 6,000 years old, and was originally the wife of Kabulu-Kagoro, now his priestess. When translated, Kabulu-Kagoro signifies the omnipresent mighty Bulu who bequeathed fire to man.

Annually at the summer (June) solstice, a great sacrificial festival takes place in which the whole nation joins. The flesh of cattle and goats, together with grain, are offered up before their divinity, and during this feast every fire throughout the realm must be entirely extinguished and a fresh, bright one kindled. Certain mountains and hills are preferably selected as the place of the sacred sacrifice. The person of the Macomba (chief) is also supplied with the godly nimbus. At the same time the Makalanga call themselves the "Sons of the Sun." "Beyond a shadow of a doubt we are here face to face with old Semitic religious ideas."

To-day even the sun god forms the central figure of their adoration. Upon the hills are the holy places where burnt offerings are made to him and the ever-burning sacred fire guarded by the Quaraquate supplements this worship. The rocks and hills are sacred to his divine presence. Is there room for question that Bulu is the original Semitic Baal or Belus? Even so was Baal honored over the whole of the Red Sea region 3,000 to 4,000 years ago. And if in Kabulu we are able to recognize Baal, shall we not also perceive in Quaraquate a faithful reminder of his feminine side, the ancient Phenician Ashera? She was formerly the wife of Kabulu; to-day she is his priestess. Thus, then, the Sons of the Sun are in fact the remnants of the worshipers of the sun god of the ancient Semitic epoch.

Far removed from the disturbing influences of human progress, here in the wilds of central Africa, here in Makalangaland alone is preserved the worship of Baal, a religion that thousands of years ago was practised from Malacca to Cornwall and from Sofala to the Canary Islands. Up the Zambesi the surging conquerors from southern Arabia pressed and in their advance brought with them not only the art of working metals but their customs and their religion as well.

With reference now to the oft-disputed etymology of the word Ophir, Aphir (in the work it appears as Afur), let us say that in the dialect of the present dwellers in Zambesi, *fura* means a hole or a mine. The natives form even a verb, *kufura*, which signifies to dig up or uncover metal; *kufura nangura* is the equivalent of to open up iron deposits; *kufura delama*, to dig gold.

Now if *fura* be a negro corruption of the Arabic *afur*, then this must originally have meant a mine, and if it can be proven that this be not of Semitic origin, then perhaps the Himyarites in the very earliest times, before the writing of Genesis, took it from one of the African languages.

This acceptation of the derivation is greatly strengthened by a highly interesting fact, for the knowledge of which we are indebted to Prof. C. Le Neve Foster, that in Cornwall and also on the very site of ancient Phenician mines the name for a mine is to this day *wheal vor*.

That the same root with an identical significance should occur at two so widely separated points, at one time under the sway of the ancient Phenicians, is at all events well worthy of consideration. According to this, then, Ophir signifies land of mines. Perhaps the indications are not altogether correct in every particular, but later explorations will assuredly supply other important facts. At all events a trail has been blazed into the dense and forgotten past which each follower will help to broaden, and there can be no further doubt that the gold of Ophir, considered in the days of antiquity as the best and finest, came from the region south of the Zambesi. But when will the time arrive, that the puzzling questions which now overwhelm us shall be elucidated by the indefatigable energies and tireless industry of the investigators, that the oldest colony of gold diggers shall stand up before our mind's eye in all the fullness of the life that once pulsated through its veins? An example of what riddles the old ruins still propound may be obtained from the experiences of a march through the province of Rhani.

"About half after eight o'clock in the morning we suddenly came upon a round circumvallation of stone which Mr. Gramann [a member of the expedition] instantly pronounced a corral or cattle pen used by the natives and built of stone, because of the scarcity of wood.

"We soon met with more of these circumvallations and among them were some of a square or four-cornered shape. At 10 A. M., after a very fatiguing march, partly over swampy land, we rested in the midst of a whole system of similar inclosures consisting of a great four-cornered base wall, round about which were circular walled inclosures. The architecture was cyclopean, without any traces of hewing or cutting. The stones, which were from 2 to 4 feet high, often strewed upon the ground, hinting only at former walls. We shortly reached the bottom of the eastern hill, at the foot of which ran a rippling brook, and in this vicinity these stone structures became more confusing than ever. Circling about the hillside in the form of terraces one wall ran above another. Upon open places possessing every appearance of having been artificially cleared stood more of the square inclosures, just as we had observed them below, and they conveyed the impression of dwellings in the state of ruinous decay.

"Bounding restlessly through this ancient settlement the brook seemed to have been artfully confined within its course, the direction of which was regulated to suit the requirements of the one-time inhabitants. Below these structures and slightly removed from them were scattered here and there, dozens—even hundreds—of heaps of quartz detritus, evidencing beyond question intentional accumulations.

"We could not disabuse our minds of the impression that here we stood upon the site of some earlier human activity, but the stillness of death reigned over the scene. Every surrounding called vividly to our mind 'Dornröschen's castle.' Meditating mutely upon the picture actually before us we could but conclude that if these piles of crushed quartz had in fact any connection with those early mining operations, then they must have been hurriedly abandoned; the work must have been suddenly ended by some dire catastrophe. If again they bore no such connection, what might be their meaning here? Confused, and still groping in the impenetrable darkness of the past, we continued our weary journey, crossing the eastern chain of hills by means of a natural pass.

"The path led us along by a succession of these buildings, which proved for the most part beyond our comprehension. At times it seemed as if the paths were hedged in between two beddings of stone winding in the most wonderfully serpentine fashion; again, upon huge granite blocks there lay stones whose only object seemed to be to compose fantastic figures. Our impressions became less and less definable from hour to hour, uncomfortable, indeed, almost gruesome. Furthermore, the masses of artificial stone-heaps, no longer of quartz alone, but also of granite and slate-rubble, cropped up as far as the eye could reach, some of them heaped up regularly in rectangular piles, much as we pile up paving stones, others of circular form, and again others irregularly shoveled together. Very often we came upon walls of granite or slate resembling the curbings around our fountains, containing piles of other kinds of stone rubble instead of water.

"At intervals between these we encountered both round and square heaps of stone rubbish which we concluded must be remnants of human habitations. Sometimes the objects before us seemed to indicate an end, a *raison d'être*, and again it seemed to us as if we were in a land formerly inhabited by a community of lunatics.

"The feeling that we were unable to comprehend what we saw with our eyes had a most depressing effect upon our spirits, even causing a sensation of anxiety. 'Run away,' cried the bird whose note fell never so frequently upon our ear as on this uncomfortable morning.

"Our guides were interrogated as to what all this meant. 'The ghosts have done this!' they answered. 'Bosh! Ghosts! No, indeed; human beings have undoubtedly been at work here. Do you not know anything about them?' 'This is no land of men; this is the land inhabited by the souls of the departed dead. Human beings are afraid to dwell here—yes, even to wander through the land alone. It is the land of the dead!'

"In other sections again, as in Inyanga, were found well-like depressions, varying from 10 to 15 feet in diameter, walled in carefully with cyclopean masonry. From 15 to 20 feet deep they were and supplied with subterranean passages. Springing from their central points there grew, almost without exception, old trees. What was their original purpose? Were they slave pens? Or were they gigantic cisterns into which the ancient gold diggers conveyed water and in which they washed the gold from the sand?

"In other localities the sides of the hills looked like the striped flanks of a zebra. When we approached to see we recognized in these stripe-like formations the immense terraced structures which toiled along laboriously up the mountain one above another. These numberless ancient mines are by no means exhausted, and even now modern gold seekers have taken up the work so mysteriously abandoned by the Phenicians thousands of years ago.

"Many of the old aqueducts have been repaired and serve the sons of another race of beings, who, even as did those argonauts of 3,000 to 4,000 years ago, find themselves well nigh overcome by the irresistible power of gold."—Translated for the Scientific American Supplement from Die Gartenlaube.

[Concluded from Supplement No. 1502, page 24074.]

THE RADIATION AND EMANATION OF RADIUM.

Part II.

By E. Rutherford, M.A., D.Sc., F.R.S., Macdonald Professor of Physics, McGill University, Montreal.

The effect of the continuous production of the emanation on the radio-activity of radium will now be considered. Solid radium bromide, in a dry atmosphere, gives off very little emanation into the air. This is not due to stoppage of the production of the emanation, but to its inability to escape from the mass of radium. The emanation is stored in the solid, and can only be released by heating or dissolving the radium.

Suppose that a small quantity of solid radium bromide, some time after it has been made, is heated in order to drive off the emanation, which is then drawn off and mixed with air in a closed vessel. The activity of the radium is at once diminished, and in the course of four or five hours reaches a minimum value—the activity, measured by the α rays, possessing only one-quarter of its original value. This gradual decay of the activity to a minimum is due to the dying away of the excited activity produced in the mass of the radium by the emanation stored in it. At the same time, the radium has almost completely lost, for the time, its power of emitting β and γ rays. This loss of activity by the radium is not permanent, for the radiating power of the radium spontaneously increases again, and, after a month's interval, has nearly reached its original value.

Let us now consider the emanation which was separated by heating the radium. In a closed vessel, its power of discharging an electrified body at first increases for several hours. This is due to the excited activity produced by the emanation on the walls of the containing vessel. The emanation loses its activity in a geometrical progression with the time. The activity falls to half value in four days, a quarter value in eight days, and so on. The curve of decay of activity of the emanation is shown graphically in Fig. 6. While the emanation is losing its activity, the radium from which it was separated is recovering its lost activity. This is due to the continuous production, by the radium, of emanation which is retained as already described; since the emanation itself radiates, the activity of the radium increases with the time. The curve of recovery of activity, due to the growth of fresh emanation, is shown in the same figure. The two curves of decay and recovery are complementary to each other. When the emanation has lost half its activity, the radium has spontaneously regained half of its lost activity. The sum total of the activity of the separated emanation, together with that of the radium from which it has been removed, is always equal to that of the original radium. It would appear as if the separated emanation and the radium were connected by some subtle and intricate mechanism, so that any decrease of the radiating power of the one is compensated by an equal increase in the other. The connection, however, becomes clear if it is remembered that radium is always manufacturing fresh emanation at a constant rate, and that the emanation is always losing its activity in consequence of changes occurring in it. When the emanation is driven off from the radium, fresh emanation is produced and stored up in the radium. If the emanation did not lose its power of radiating with the time, it would be expected that the activity of radium would continue to increase steadily with the time. Since, however, the emanation is always changing and losing its activity, a stage must be reached where the production of fresh emanation just compensates the loss of activity of the emanation stored up in the radium. Just as the population of a country remains constant when the number of births is equal to the number of deaths, so the activity of radium reaches a steady limiting value when the number of particles of emanation produced per second is exactly equal to the number of particles which lose their power of radiating in the same time.

In this continuous production of new kinds of active matter, which only radiate for a limited time, lies the key to the explanation which has been advanced to account for the phenomena of radio-activity. What process, occurring in radium, can account for its remarkable behavior, for the spontaneous and unceasing projection of α and β particles, the rapid emission of heat, and the production of a gas endowed with new and surprising properties? It is obvious that some sort of chemical explanation is necessary to account for the appearance of new kinds of matter. But, on the other hand, the laws which control the production of this matter are very different from those of ordinary chemical change. Temperature, which has such a marked influence on ordinary chemical reac-

tions, has no appreciable effect in changing the processes occurring in radium. The activity or heating effect is not affected by plunging radium into liquid air; and, so far as observation has gone, the rate of decay of activity of the emanation is unaltered by the most drastic physical and chemical treatment. If, however, it is supposed that the changes occur in the atoms of the radio-element itself, it is not to be expected that temperature would have much influence, for the experience of chemists in failing to break up the atoms into simpler forms, shows that wide changes of temperature have little effect in altering the stability of the chemical atom.

The theory that the phenomena of radio-activity are due to the disintegration of the radio-atoms was advanced more than a year ago by Mr. Soddy and the writer. This theory accounts in a simple way for all the complicated phenomena manifested by radio-active bodies, and welds together a series of apparently disconnected facts. Let us, for brevity, consider the application of this theory to explain the properties of radium alone. It is supposed that a very small number of the radium atoms—about one in every hundred thousand million will suffice—become unstable every second and break up with explosive violence. A part of the atom—the α particle—is expelled with great velocity. The expulsion of a particle which has a mass about twice that of the hydrogen atom, leaves the radium atom lighter than before, and must change its chemical and physical properties. The radium atom minus the expelled α particle, on this view, constitutes the atom of the "radium emanation." The atom of the emanation is also unstable; and, on an average, half of the total number produced break up in four days, each atom as it breaks up expelling another α particle. The emanation as a result is changed into another type of matter—emanation X, as it has been named—which behaves as a solid. This, in turn, is unstable, and the process of disintegration goes on from stage to stage till in the fifth stage, in addition to the α particle, the β particle is thrown off with its accompaniment, the γ ray.

The different substances produced as a result of the disintegration of the radium atom, together with the nature of the rays emitted at each change, are shown diagrammatically in Fig. 7.

At least five distinct substances are produced as a result of the disintegration of the radium atom. The emanation is a chemically inert gas, while the succeeding products behave like metallic substances which are readily soluble in some acids, and are volatilized by heat. Each of these substances differs from an ordinary chemical element, inasmuch as it is not permanent, but is continuously and rapidly changing into another kind of matter. The products of the disintegration of the radium atom may thus be considered as transition elements which have a very limited life. Each of the products is transformed according to a definite law, and at a perfectly definite rate. After any interval t, the number of atoms, N, of any given kind of matter which remains unchanged is given accurately by the equation, $N = N_0 e^{-\lambda t}$ when N_0 is the initial number of atoms present, λ is the constant of change, and e is the base of the Napierian logarithms. The time, T, which elapses before half the amount of each transition element is transformed is shown in the following table:

Name of Substance.	Time, T.	Remarks.
Radium		
> Emanation	4 days	1st product.
> Emanation X (1st change)	3 minutes	2d product.
> Emanation X (2d ")	21 minutes	3d product.
> Emanation X (3d ")	28 minutes	4th product.
> Emanation X (4th ")	very slow	5th product.
> Final product		

The transformations of each of the products of radium, with the exception of the third, are accompanied by the emission with great velocity of α particles alone (Fig. 7). It is remarkable that the β and γ rays are only emitted during the changes in the fourth product, i. e., during the last *rapid* change which takes place in the radium atom.

The fifth product of radium differs from the others in its extremely slow rate of change. The evidence so far obtained points to the conclusion that probably several hundred years would be required before half this matter is transformed. Since this substance is being continuously produced by the radium, and changes very slowly, it should gradually collect in some quantity in matter which contains radium. There is at present a good deal of evidence that the radio-active substance separated from pitchblende by Marckwald, and called by him radio-tellurium, is in reality the fifth product of the disintegration of the radium atom.

Since the radium products are unstable and rapidly breaking up, we cannot regard them as identical with any known kind of stable matter.

Each of the radio-active products is found to possess distinctive chemical and physical properties which serve to distinguish it, not only from the preceding and succeeding products, but also from the parent element. The emanation is a heavy gas, which can be condensed by the action of extreme cold; like the gases of the helium-argon family, it is chemically inert. On the other hand, the solid products derived from the emanation are soluble in some acids; they are volatile at high temperatures, and can be partially separated from each other by their difference in volatility or by electrolysis.

With the exception of the emanation, none of the products of radium has been collected in sufficient quantity to be examined by direct chemical methods. The amount of each product to be obtained from a given quantity of radium depends on the rate at which it breaks up. When a state of radio-active equilibrium

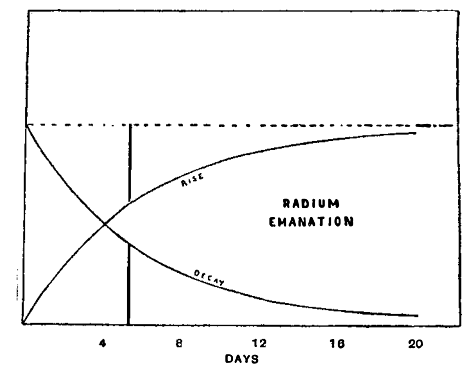


Fig. 6.—Curves Showing Decay of Activity of the Emanation, and Recovery of Activity of Radium.

is reached, the number of atoms of any product appearing in unit time must equal the number disappearing; but, since the products break up at different rates, the number of atoms must be greater in the case of the more slowly changing product. It can be calculated that the weight of emanation (half of which breaks up in four days) obtainable from 1 gramme of radium bromide is about 1-100 of a milligramme; while the weight of the fourth product (half of which breaks up in twenty-eight minutes) is about 3-100,000 of a milligramme—a quantity too small to be detected by the chemical balance. Thus it appears that the radio-active products resulting from the disintegration of the radium atom can never be collected in any great quantity on account of their limited life. The inactive products, however, must increase in quantity so long as there is any radium present, and we may hope to find them in radium ores in measurable quantities. The inactive products of radium are the expelled α particles and the final product.

Now the mineral pitchblende, in which radium occurs, contains in small quantity a large proportion of the known elements; the presence of the rare gas helium is noteworthy. Helium is only found associated with the radio-active minerals, and its presence in them has always been a matter of surprise. Mr. Soddy and the writer suggested, in 1902, that helium might prove to be a disintegration product of the radio-elements. This hypothesis received strong support from measurements of the mass of the projected α particles of radium, for, within the limit of experimental error, these appear to have about the same mass as the helium atom.

This suggestion has been verified in a brilliant manner by the recent experiments of Sir William Ramsay and Mr. Soddy. They found that helium always appeared in a closed tube in which the radium emanation had been stored for some time. The results indicate that helium is produced from the emanation as it gradually breaks up and disappears. There has been a tendency to assume that helium is a final product of the disintegration of the atom of the emanation, but the evidence so far obtained rather points to the conclusion that helium is in reality the expelled α particle. If this is the case, helium should be produced from each of the radium products which emit α rays; but the experimental difficulties in an investigation of this

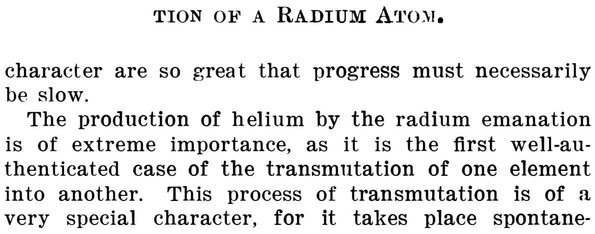


Fig. 7.—Diagram to Represent the Disintegration of a Radium Atom.

character are so great that progress must necessarily be slow.

The production of helium by the radium emanation is of extreme importance, as it is the first well-authenticated case of the transmutation of one element into another. This process of transmutation is of a very special character, for it takes place spontaneously, and at a rate that is independent of our control. In order to explain the production of helium from radium on strictly chemical lines, it has been suggested that helium is not a true element, but is in reality an unstable compound of helium with some known or unknown element, and that this compound is steadily breaking up with the liberation of helium. It must be borne in mind, however, that this postulated compound is very unique in character, for it is necessary to suppose that, unlike any other molecular compound, it breaks up with the expulsion of charged particles moving with enormous velocity, and that the energy liberated during these changes is about one million times greater than the energy liberated in the most violent chemical reaction. In addition, it is necessary to suppose that the process by which helium is liberated is unaffected by wide changes of temperature—a result never before observed in any chemical reaction.

So far as observations have yet gone, radium is a true element in the ordinary accepted chemical sense. It has a definite spectrum and atomic weight, and in chemical behavior is closely allied to the well-known element barium. On the disintegration theory, the helium and the radio-active products appear as a consequence of the disintegration of the radium atoms. The difference in the two points of view is, to a large extent, one of nomenclature alone. The chemical atom is defined as the smallest chemical unit which enters into combination with other substances, and which cannot be broken up by the action of physical and chemical forces at our disposal. This is true, so far as we know, in the case of radium; for the breaking up that does occur is spontaneous, and cannot be accelerated or retarded by chemical of physical agencies.

Taking into account the novel character of the changes occurring in radium, and the enormous emission of energy, it appears more reasonable to suppose that these appear as the result of changes of quite a new character in matter—a breaking up of the chemical atom rather than of the chemical molecule.

Since radium is continuously breaking up with the expulsion of α particles and the production of new kinds of matter, a given quantity of radium must, in the course of time, disappear as such, and be transformed into inactive substances. It can be calculated that, in a gramme of radium bromide, about half a milligramme is transformed per year. In the course of about 1,500 years half the radium present has been changed. If the whole world had been initially composed of pure radium, the amount of radium remaining 30,000 years later would not be more than one part in a million, i. e., about the amount observed to-day in a good specimen of pitchblende. Since there is every reason to believe that the earth's crust is very much older than this, we are forced to the conclusion that radium must, in some way, be continuously produced from the materials of the earth. In looking for a possible parent of radium, the elements uranium and thorium both suggest themselves, for both fulfill the necessary condition of having an atomic weight greater than that of radium, and both are always found in minerals from which radium is derived. In addition, both of these elements have a very long life compared with radium. Since the activity of uranium and thorium is less than one-millionth of that of radium, its life should be about one million times longer, i. e., a length of time of over 1,500 million years would be required before half the uranium present has been transformed. In some respects uranium seems the most likely parent of radium, for minerals rich in uranium are found to contain the most radium, while minerals rich in thorium often contain little radium. It remains for future work to give a definite answer to this question. If radium is produced from uranium, radium would occupy the same position in regard to it as the radium emanation does to radium, the only difference being that radium has a much longer life than its emanation. After the lapse of a few thousand years, the quantity of radium present in the mineral would reach a constant value, the production of radium balancing the loss by disintegration. The quantity of radium present in a mineral should, on this view, be always proportional to the amount of the parent element.

Much attention has recently been directed to the distribution of radio-active matter in the earth's crust and atmosphere. Its presence and amount have been determined by observations on the rate of discharge of an electroscope—a method transcending in delicacy even spectrum analysis.

The experiments of Elster and Geitel, J. J. Thomson, Strutt, and others, have shown that radio-active matter, while found in the greatest quantity in the mineral pitchblende, is widely diffused in nature. Radio-active emanations occur everywhere in the atmosphere, in well water, in hot springs, and in surface water. Elster and Geitel have found that the earth's crust is all more or less radio-active. If air is sucked up through a pipe let down into the ordinary garden soil, it is found to be impregnated with emanations. The amount of radio-active matter varies in different localities, but is most marked in clays and in the mud obtained from hot springs.

Since the presence of radio-activity is an indication that matter is breaking up with an enormous emission of energy, it is natural to ask what part radio-active substances play in cosmical physics.

On the assumption that the earth was formerly a molten mass, Lord Kelvin has estimated that to cool down to its present state it would require a period of from twenty million to one hundred million years. This calculation places a definite maximum limit to the time that has elapsed since the earth became cool enough to support life. In Thomson and Tait's "Natural Philosophy," Appendix E, the following sentence occurs, after a discussion of the probable age of the sun and earth: "As for the future, we may say, with equal certainty, that the inhabitants of the earth cannot continue to enjoy the light and heat essential to their life for many million years longer, unless sources

of heat—now unknown to us—are prepared in the great storehouse of creation."

In the light of the discovery of radium and other radio-active substances, which in their changes are able to emit an enormous amount of energy, this remark seems almost prophetic. Assuming the average temperature gradient (1.50 deg. F. per foot descent from the earth's surface) and the conductivity of the rocks of the earth taken by Lord Kelvin, it can be calculated that the amount of heat conducted to the earth's surface each year and lost by radiation could be supplied by the presence of radium (or an equivalent amount of other radio-active matter) to the minute extent of about five parts in ten thousand million by weight. The observations of Elster and Geitel show that the amount of radio-active matter present in the soil is of this order of magnitude. Thus it does not appear improbable that the temperature gradient observed in the earth may be due to the heat liberated by the radio-active matter distributed throughout it. If this be the case, the present temperature gradient may have been sensibly constant for a long interval of time, and Lord Kelvin's computation may only supply the minimum limit to the age of this planet. Thus the earth may have been at a temperature capable of supporting animal and vegetable life for a much longer time than estimated by Lord Kelvin from thermal data. Similiar considerations apply to the question of the sun's heat; for the presence of radium in the sun, to the extent of about four parts in one million by weight, would of itself account for the present rate of emission of heat. The discovery of the radio-active elements, which in their disintegration liberate enormous amounts of energy, thus increases the possible limit of the duration of life on this planet, and allows the time claimed by the geologist and biologist for the process of evolution.—Technics.

PROTECTION FROM LIGHTNING.*

By Prof. Dr. Fr. Neesen, of Berlin.

In laying down rules for protection from lightning, we have three classes of protectors to consider:

1. Lightning protectors for buildings.
2. Lightning arresters for low-potential circuits.
3. Lightning arresters for high-potential circuits.

In the first class direct connection of the whole construction with the earth is possible, in the other classes not.

Arresters for high-potential circuits must contain automatic means of breaking the short-circuit of the working current made by the escape of the lightning discharge to earth.

The construction of a protector depends on the definition of its duty. This would seem to be, obviously, protection from damage by lightning, but it is important to know how this protection can be given. Some regard the function of the protector as essentially preventive by rendering harmless, by so-called slow discharge, the electricity accumulated in the clouds before a flash can take place, but they concede that the protector, if it falls short of this duty, must be able to carry off the lightning from the apparatus to be protected. Others lay stress on the latter function, and regard the slow discharge as altogether subsidiary. The choice of one or the other view has more than theoretical interest. If the first is correct, as many points as possible must be employed and kept in perfect condition; if the second is the right one, the importance of points almost vanishes. A striking proof that points play a very unimportant rôle is given by the following experiment of Chwolson. (Fig. 1.)

The electricity accumulated in the clouds may be represented by the charge of the inner coating of a Leyden jar which is maintained by an electrical machine. The inner coating is connected with a metal rod provided with a movable arm, *b*, which ends in a cup *c*. Near the jar and within the sphere of influence

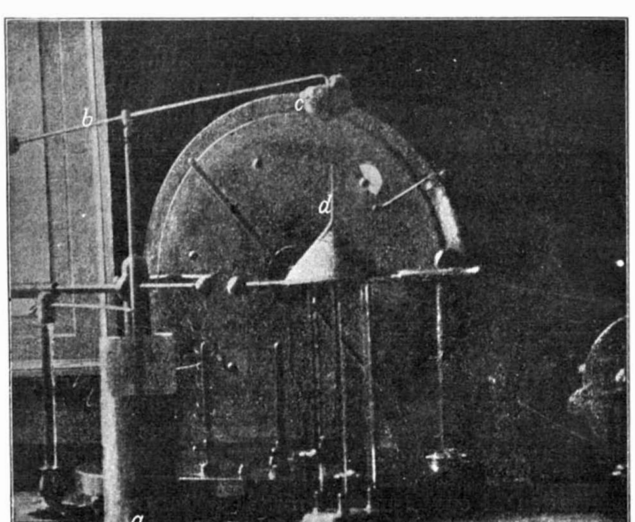


Fig. 1.

of the cup stands a little house provided with a high lightning rod, which is connected to earth. If the arm is so placed that the cup is directly over the lightning rod, *d*, no discharge of sparks occurs when the machine is turned, because the cup is slowly and continually discharged through the point. But if the arm is turned away and brought back toward the point with a jerk, a spark discharge occurs. Indeed, the jerk need not be given, for the attraction between the charge of the cup and the induced charge of the point is enough to cause a sudden approach which makes the silent, sparkless discharge impossible. Now, if the small charge of a Leyden jar cannot escape during the approach of the cup, the immensely greater charges of the air can surely not be dissipated in this way. Millions on millions of points, like the leaves and twigs of a forest, are needed. But even in a forest it often happens that a single tree is struck by lightning.

Hence the character of the points is unimportant, as conductors without points can draw the discharge to themselves from other parts of the building. In recognition of this fact, intelligent makers of light-

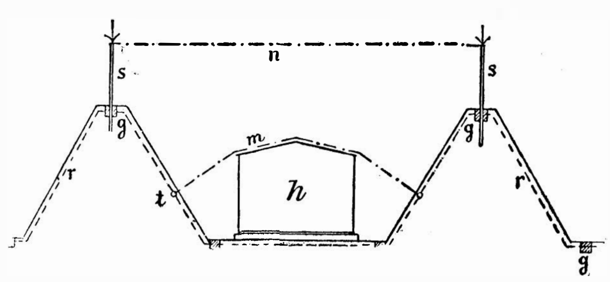


Fig. 3.

ning protectors have discarded the points of platinum, carbon, etc., once so highly esteemed.

LIGHTNING PROTECTORS FOR BUILDINGS.

In order to review the laws governing the construction of lightning protectors, it is necessary to have a clear understanding of what takes place on the approach of an electrically-charged cloud.

All objects on the surface of the earth become charged oppositely, especially objects in which the induced electricity can move without delay or resistance, namely, conductors. Where differences of potential exist between a cloud and particular parts of the earth's surface, the greatest difference occurs, other things being equal, between the cloud and metallic conductors, provided that these are so large that the induced electricity of the same sign as that of the cloud can escape to distant points.

Lightning, therefore, tends to strike such metal parts, hence metallic collectors are placed on the roofs of buildings to attract it. Two distinct plans are followed in the arrangement of these collectors—the old plan, based on Gay-Lussac's recommendations, and the new one, which rests on those of the Belgian Melsens. The first, easier to carry out in construction, is founded on the assumption that a

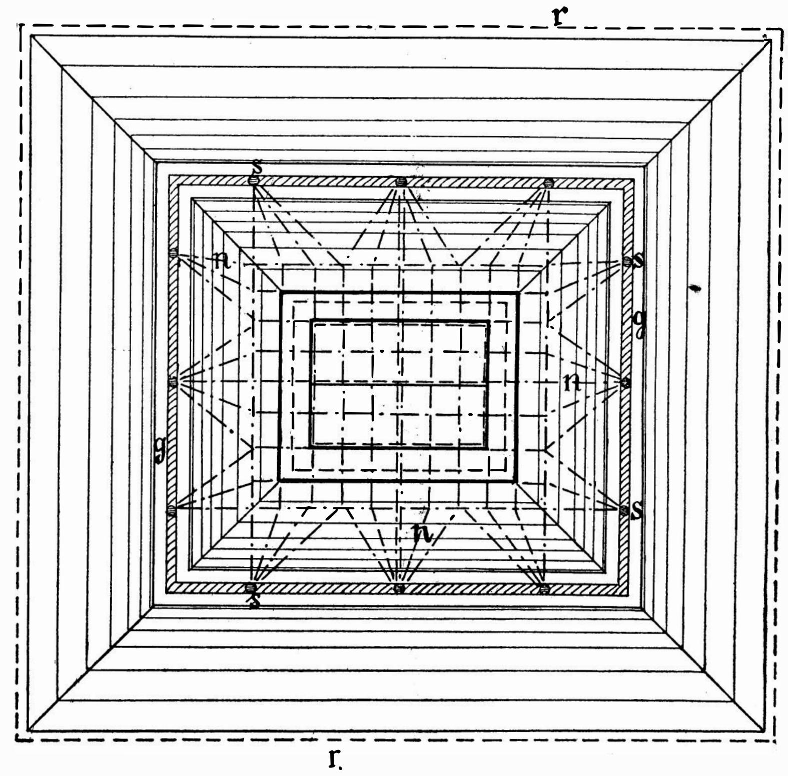


Fig. 2.

vertical metal rod protects everything within a certain cone of which the rod forms the axis. The cone was determined by the rule that a cloud in any possible position must be nearer to the tip of the rod than to any part of the building.

Many sad experiences have shown that no reliance can be placed on this rule, and it was found necessary to contract the cone more and more, until the diameter of its base was reduced to three times the height of the rod. This rule is still followed by a number of constructors, partly no doubt because it gives a simple plan for the arrangement of the rods.

But this method of calculation is not justified by the differences in the distance of the cloud from various parts of the building, differences very small in comparison with the length of the flash, which may be several kilometers. Even in experiments with sparks a few decimeters long, we see that the spark does not follow the straight and shortest line, but always shows the zigzag form characteristic of lightning. A number of other phenomena come into play which affect the path of lightning, above all air currents and motions of the electrical charges of different parts of the building, which may lead to the formation of dangerous modes of vibration. For it must always be remembered that in view of the rapid motion of clouds, we have to do, not with conditions of equilibrium, but with currents. Hence it was a happy thought of Melsens to enunciate the principle that instead of tall rods of heights computed from the rule of the protected cone, short rods should be attached to all exposed places such as chimneys and ventilators, and that the metallic connections between these rods should also serve as collectors and cover and protect the roof. The construction is more complicated, but the cost of erecting high rods is saved, and their absence improves the appearance of the building.

But the task is not completed with the construction of a good collecting device. This alone would act like the spangled tube of the lecture room, for though the rods or roof wires would receive the actual lightning stroke, sparks would pass from them to neighboring conductors and thence to earth. For the electricity of

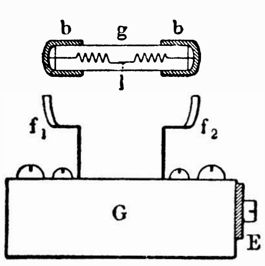


Fig. 4.

the same sign as the cloud's charge, which is repelled by this in the process of induction, also produces differences of potential which give rise to secondary discharges.

The charge accumulated on the roof conductors must therefore find immediate escape to a reservoir large enough to minimize electrical tension. Such a reservoir is the earth, hence the roof conductors are connected by wires running down the walls to special conductors, the earth connections, whose function it is to distribute the accumulated charge through the soil. In computing the dimensions of these ground and intermediate conductors, it must be remembered that the escape of a charge through a conductor occupies an interval of time, during which differences

* A lecture delivered before the Electrochemical Society of Leipzig.

of potential between the conductor and neighboring objects may be developed and cause secondary discharges. Hence several paths of escape, several wires, and ground connections are needed—how many is hard to say. Here a sort of feeling of instinctive comprehension must be the guide. As a rough estimate we may take one escape wire and ground connection for every hundred square meters. The multiplication

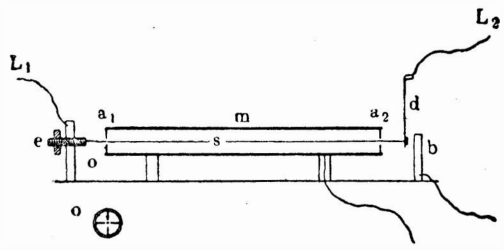


FIG. 5.

of earth wires also offers the advantage, strongly emphasized by Melsens, of shielding the interior of the building from electrical tension, as the conductors form a sort of Faraday's cage.

There are many forms of ground connections. The commonest and most effective are plates of copper or galvanized iron buried, or gas pipes driven, below the ground-water level. But the ground water is often so difficult to reach that other devices must be employed. In such cases wires radiating in various directions

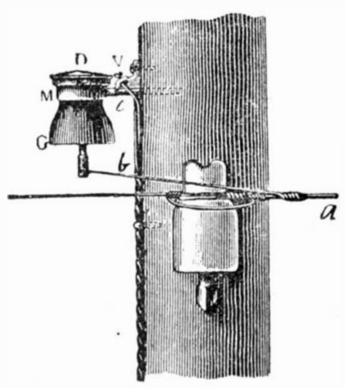


FIG. 6.

from the end of the conductor and about ten meters long may be buried very near the surface, preferably under sod or in a damp place. A narrow trench filled with small coke surrounding a strip of lead connected with the conductor has also proved satisfactory.

An example of the absurd constructions which often result from following a fixed rule is given by an Alpine shelter where, to make connection with the ground water, a wire has been led to a spring several kilometers away. Special ground connections may, and to

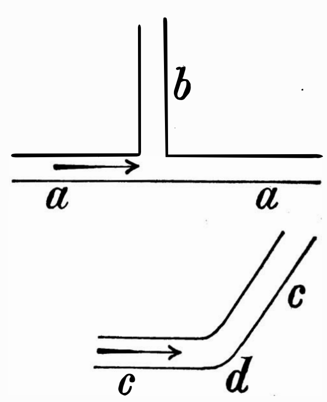


FIG. 7.

some extent must, be replaced by metal gas or water pipes, which favor the distribution of the charge better than any artificial arrangement. But as these pipes may be cut off there should always be an independent earth connection as well.

A complete Faraday's cage is generally impracticable, hence there will be electrical tension in the interior parts, particularly toward extended conductors such as gas and water pipes. Smoke pipes and heating flues should be connected at the bottom with the

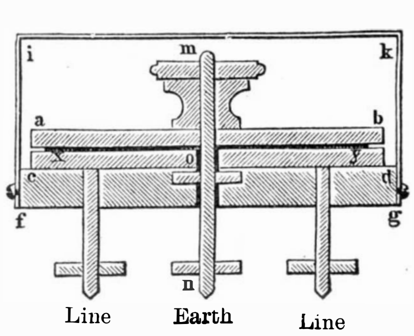


FIG. 8.

protective system. Whether this should or should not be done when these pipes do not reach the upper story is another matter for electro-technical instinct. If they are ten meters below the lightning protector, and this is well grounded, they need not be connected. Regard must be paid also to the distance between water pipes and the wires which connect the roof with the ground. If this distance is only a few meters at any point, the pipe and wire should be connected at that point unless they are connected at the ground.

Expense may be saved and the protective system improved if this is constructed simultaneously with the building and utilizes its metallic structural elements. Metal ridge plates, roof, gutters, and leaders are excellent substitutes for special constructions. But this cheapening must not be carried too far. In some buildings pointed out as models of safety metal parts have been incorporated in the protector without having good contact with each other. This has been

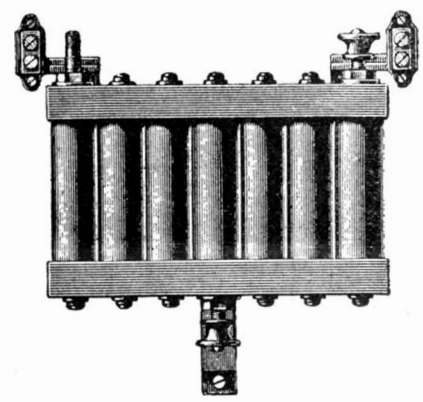


FIG. 9.

defended on the assumption that the high tension of lightning discharges can easily spring over such small gaps. This is quite true, but the sparks which necessarily occur may, and in one instance did, cause a conflagration and, besides, they retard the discharge and produce electrical oscillations, both of which effects increase the danger of lateral discharges. In the construction of a first-class protector all such defects which may impair its efficiency should be avoided. If, on the other hand, we are content with a less degree of security, or a second-class protector,

protection of such structures. The Berlin Electrotechnical Union is now diligently working at this problem and, let us hope, will soon make known its conclusions.

The vapor which rises from an oil tank is very liable to ignition by a stroke of lightning. Except for this special danger the metal tank would need no further protection than an earth connection. To protect the vapor, however, a fine-meshed wire netting should be stretched high above the tank and well grounded, so that the lightning cannot reach the densely vapor-laden air immediately over the tank. The manholes should also be always protected by self-closing Davy safety gratings. A similar arrangement is employed in the dynamite factory at Kremmel, and is illustrated in Figs. 2 and 3. A meter above

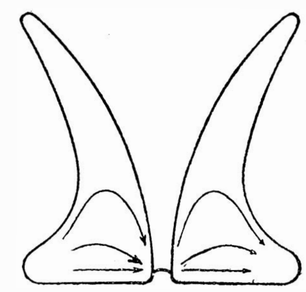


FIG. 13.

the building to be protected wires are stretched lengthwise and crosswise at intervals of a meter and attached to iron posts on the surrounding wall, from which the earth connections extend. The poles have also, perhaps unnecessarily, branching Melsens collectors. The building is further protected by a second coarse net, such as is used in powder mills.

LIGHTNING ARRESTERS FOR LOW-POTENTIAL CIRCUITS.

In electrical establishments the danger from lightning to which the line is exposed is added to that which threatens the building directly. The line is

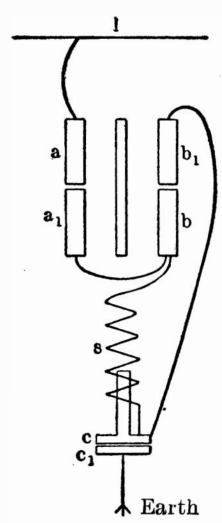


FIG. 10.

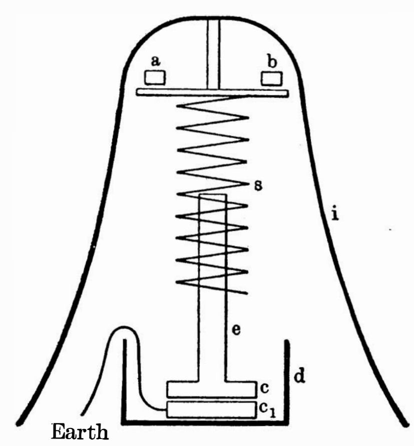


FIG. 11.

we may disregard small gaps. It is perfectly legitimate to speak of different degrees of protection. Even an imperfect conductor gives better protection than none. Except in very special cases, there is no ground for the common saying that a poor lightning rod only increases the danger of being struck. The approaching cloud charges not only the rod, but the whole building, and the ground. The capacity of the latter is always extremely great compared with that of the building, and their ratio is not affected by the small metallic surface of the rod. But the building itself

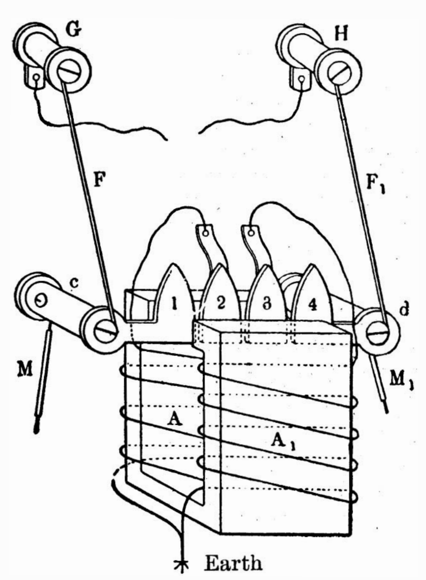


FIG. 12.

offers more favorable points for discharge than the ground does, and is as likely to be struck without a rod as with one.

Some establishments, such as oil tanks, powder mills, and, above all, dynamite factories, need especially careful protection because of the great danger of ignition from sparks. Several recent explosions caused by lightning have recalled attention to the

charged to a varying extent by atmospheric electricity, and these varying charges result in currents which must become very strong when the line is struck by lightning. The apparatus is exposed to danger from these currents, which may destroy it and kill men who are near it even when the line is not actually struck.

In devising methods of protection it should be borne in mind that these currents, usually, are not constant but intermittent, or even consist of electrical oscillations which must occur on the line, even if the

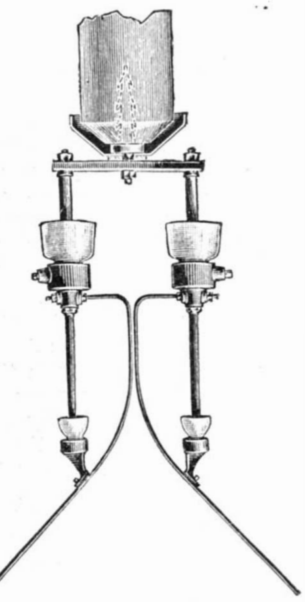


FIG. 14.

lightning flash itself is not an oscillating discharge, as it is often asserted to be, though, so far, without the slightest proof. Aside from cutting out the apparatus from the line on the approach of a storm, immunity from damage has been sought in two ways. Arresters of the first class automatically disconnect the apparatus from the line when the current becomes too strong, while those of the second seek to provide

for the lightning discharge a way of escape which the working current cannot follow. To the first class belong especially safety fuses, strips of easily fusible metal which form part of the circuit and are melted by a strong current. An example is the so-called cartridge arrester, much employed in telephone stations. (Fig. 4.) A glass tube, *g*, contains two spiral wires which hold between them a piece of easily fusible alloy, *d*. The tube is inserted between springs, b_1 b_2, which are connected respectively with the apparatus and the line. It is evident that this device cannot protect the apparatus from an actual lightning stroke, in which the electrical tension increases so suddenly that the apparatus is in danger before it is cut out by the fusing of the plug. Such devices are of value only as safeguards against the weaker and less sudden currents due to fluctuations in the charge of the air, and as complements to arresters of the second class.

The latter offer to the lightning a way of escape to earth over a spark gap which allows the high-tension lightning, but not the working current, to pass. With this object a piece of metal connected with earth is placed about a millimeter away from another piece of metal attached to the line. These pieces are of various forms, including points, plates, continuations of both, and simple wires. The employment of opposed points or edges rests on the theory that the pointed form facilitates discharge. This is the case, however, only when the point is made the positive electrode, and even then it must be remembered that the discharge of the great quantity of electricity involved in lightning cannot be confined to the point, but must take place over the whole surface. Hence the plate form is preferable. To avoid the danger of short-circuiting by fusion in plate arresters, it is advantageous to make them of carbon instead of metal. The carbon must, of course, be of excellent quality, not easily disintegrated.

Some arresters contain cylindrical conductors and present themselves as earth-connected electrodes surrounding the line. Saunders's arrester (Fig. 5) is employed to advantage on ocean cables. A wire, *s*, connected with the line, *L*, is surrounded by a metal cylinder, a_1, *m*, a_2, which is connected to earth.

The ends of the cylinder are furnished with transverse sharp points which almost touch the wire. The other end of the wire is connected with the apparatus through a fusible plug arrester, *d*, which cuts out the apparatus if a very strong current flows through the line.

In the spiral arrester used in telephone stations, on the other hand, a fine insulated wire is wound on an earth-connected metal core. Powerful atmospheric discharges spring from the wire to the core and, at the same time, melt the fine wire and thus produce a short circuit through which the charge of the wire passes directly to earth, without affecting the apparatus.

Arresters of this sort are attached to the line wire inside the station and also at poles along the line, where, however, the attachment is made in a manner open to serious objection. The same objection applies to the customary arrangement of the arresters for high-potential circuits, to be described presently.

The arrester plate does not form a part of the line, but is inserted on a shunt, as shown in Fig. 6. A branch wire, *b*, leads from the line, *a*, to one plate of the arrester, the other plate of which is the cover, *D*, which is connected to earth through *V*. The space between the plates is protected from moisture, which would ground the line, by a porcelain shield, *G*.

The attachment of the arrester to a shunt constitutes the defect, as will appear from a comparison with a water circuit which gives, in essentials, a good image of an electrical one. (Fig. 7.) After a permanent state of flow is established, the branch, *b*, will carry off from the main channel, *a*, a quantity of water conditioned by the cross sections and slopes of the two. The result is very different when a mass of water falls suddenly and with great velocity into *a*. The branch channel, at first, takes but very little of the flow. Again, a calmly-flowing stream passes the bend in the channel *c*, without injuring the dike at *d*, but a sudden flood endangers the dike despite the open channel beyond. Similar conditions exist in the action of a lightning arrester. If it is on a branch wire it does not take the full charge imposed on the line by a sudden electrical impulse.

If, however, the arrester is inserted directly in the line, the desired rupture of the dike, the discharge to earth, follows in accordance with the analogy just given. Hence it appears to be more correct also to connect plate arresters to the line or apparatus in the manner shown in Fig. 8. Here the current enters the plate at right angles and leaves it in the same manner, but in the opposite direction.

For the facilitation of such electrical breaking of bounds use is made of the resistance which the current offers to change of direction by inserting spirally-wound wires between the arrester and the apparatus to be protected. These are called inductance coils, and the peculiar and great resistance which they oppose to sudden impulsive discharges is termed inductance. This apparent resistance proceeds in reality from a counter electromotive force developed in the coil by the sudden disturbance. The arrester and its ground connection, on the contrary, must have as little inductance and hence as little curvature as possible.

There is another defect common to nearly all installations, including those of high-potential circuits. This also may be illustrated by a hydraulic analogy. Often, to save a threatened district from flood, a dam is broken at some other point. A small opening will not suffice; the break must be large enough to carry off the water. Just so must the break through which the electrical charge is to escape to earth be large enough for its purpose. In technical language the arrester must possess sufficient capacity. In lightning we have to do, not with thin sparks, but with flashes meters wide. The conditions of discharge in an electrical machine are not a safe guide.

LIGHTNING ARRESTERS FOR HIGH-POTENTIAL CIRCUITS.

On such a circuit the arrester, after carrying off the atmospheric electricity, must break the short circuit of the working current caused by the discharge. For when a large spark passes between the arrester plates, it heats the air so greatly that the ordinary high-potential current is able to follow, and is thus diverted to earth, or short-circuited.

There are a great many high-potential arresters, based on diverse theories the validity of which can be proved by experience alone.

A simple means of preventing the short circuit consists in the multiplication of sparks in the arrester, so that the tension of the working current cannot bridge the gap, even after the way has been prepared by the lightning stroke. In plate arresters this is effected by means of a series of plates with a gap between each pair. But this form has not stood the test of practice, for though it prevents short-circuiting it does not entirely equalize the tension on the line, so that in many cases apparatus lying beyond it has been injured.

An improved form is the cylinder arrester (Fig. 9) which is based upon the fact that the passage of a spark between certain metals, such as zinc or aluminium, so increases the resistance of the gap that the passage of a second spark becomes much more difficult. The cause of this increased resistance is not yet clearly understood. It is assumed that a non-conducting coating of oxide is formed, but this could occur only at the point where the spark passes, and at other points the path would still be open.

The number of cylinders used depends upon the working voltage. Cylinder arresters appear to be used chiefly in America. In Germany they have proved satisfactory on alternating, less so on direct-current circuits.

Electromagnetic spark extinguishers are very largely used for the automatic rupture of the short circuit. In some of these the short-circuit current traverses a coil with a movable iron core, by the action of which the plates between which the spark passes are separated so widely that the short circuit is broken. (See Figs. 10 and 11.) By surrounding the plates with oil the suddenness of the rupture is greatly increased. The oil vessel is shown in *d*, Fig. 11. If the coil were inserted in the main line, its inductance would hinder the discharge to earth. It must, therefore, be put on a branch wire, as in Fig. 10, so that the greater part of the discharge can pass by to earth. This form has stood the test of experience better than the simple plate arrester, but only for comparatively low voltages. It is, furthermore, easily destroyed. Sixteen such arresters were rendered useless last year in Rottenburg, where the magnetic extinguishers of another class, since introduced, have as yet suffered no damage. These are based upon a direct action of the magnetic field due to the short circuit upon the path of the spark. The lines of force projected by a magnet have the same effect on a spark as on any other conductor, but as the ends of the spark are fixed, the magnetic action involves a lengthening of the spark, which at last breaks because the working voltage is too low to maintain a spark of the increased length. The spark is blown away from the magnet which, therefore, is termed a blow magnet. Fig. 12 shows the arrangement.

The short-circuit spark is formed between the pieces 1, 2, 3, 4 and blown by the electromagnet *A* upward along their curved edges to their points. These pieces are usually horn-shaped, as in Fig. 13, whence the name horn arrester. In this form, even without an iron magnet, the spark is driven upward and therefore lengthened partly by the upward current of heated air, partly by electromagnetic action. Fig. 14 shows an arrester constructed on this principle by Siemens & Halske. Two wires, one connected with the line, the other with earth, approach each other from opposite directions, gradually become parallel and then bend sharply away from each other. Their distance can be varied, but is usually one millimeter at the point of closest approach. Of all forms these horn arresters have best stood the test of experience, at least in Germany.

A serious inconvenience is the frequent connection of the wires by snow, rain, or dust and the resultant short-circuiting of the current even without a lightning stroke. Inclosing the apparatus in a box is suggested as a remedy.

In the attachment of all arresters for high-potential circuits the error of putting them on shunts is made. Another general defect is the smallness of the surface of discharge, the so-called capacity. To these two circumstances, probably, is due the occasional failure of every one of the forms described to afford protection.

That with proper regard to these two points protection may be assured is shown by the example of the electrical equipment of the Baltic and North Sea Canal. Here the protector is a barbed wire stretched parallel to the cable and grounded at intervals of two hundred meters. The discharge takes place directly from the line and over a large surface. No damage from lightning has yet occurred to lamps or dynamos, though the cable has been slightly injured.

Experience like this is the best guide in the construction of lightning arresters. Thanks to the initiative of the Berlin Electrotechnical Union, it has been possible to found a collection of results of practice from which, though only two years old, very valuable conclusions have been drawn. It does not seem too bold to hope that through the co-operation of all interested as secure protection for both low and high voltage circuits as we now have for buildings will eventually be found.

CONTEMPORARY ELECTRICAL SCIENCE.*

ARC BETWEEN METALLIC OXIDES.—J. Stark has found that in certain circumstances an arc is more easily established between metallic oxides than between the metals themselves. He uses a vacuum tube in which the main current passes between the anode and the cathode and produces the ordinary glow phenomena, while the secondary current passes between electrodes at right angles to the primary electrodes, and is extinguished as soon as the main current is interrupted. At a pressure of over 50 volts and a vacuum of less than 0.5 millimeter, the presence of a film of metallic oxide, or of a few fragments of it, facilitates the production of an arc between the secondary electrodes. The author gives the following explanation of this effect. The lines of electric force proceed straight from the anode to the cathode, but if the latter bears a fragment of metallic oxide, they curve round it and enter the cathode at some other point. Nevertheless, the positive ions, having acquired a certain amount of momentum, go straight on, and impinge upon the oxide, thus increasing its temperature, and causing it not only to conduct electricity, but to evolve electrons in large quantities. Wehnelt has already shown that metallic oxides project more electrons than pure metals at high temperatures, and hence the arc, which requires a liberal supply of electrons, is more easily formed at the oxide than at the pure metal. At atmospheric pressure, the author obtained a small arc between a carbon anode and a cathode of thorium oxide at a pressure of 1,800 volts and with a current of 7 milliamperes. The anode remained quite dark.—J. Stark, Physikal. Zeitschr., February 1, 1904.

COMPARISON OF HEAT AND N-RAY EFFECTS.—R. Blondlot found recently that the effect of N-rays upon a faintly luminous fluorescent screen consists not so much in an increase of the luminosity as in a change in the direction of emission. Thinking that the well-known effect of heat in increasing the luminosity of fluorescence might show a similar behavior, he observed the emission of heated screens in various directions. He found, however, that the emission increased in the same proportion in all directions, and thus obtained a valuable criterion for distinguishing between the effects of N-rays and those of heat. He describes a striking experiment which serves to clearly bring out the essential difference between heat and N-rays. He covers a screen measuring 5 centimeters by 12 centimeters uniformly with calcium sulphide, and makes it feebly luminous. He heats a portion of it, whereupon it becomes brighter than the rest. After that, he exposes one-half of the same screen to the action of N-rays given out by a Nernst lamp. The intensity of the rays is so feeble that no visible effect is produced upon the screen. Then he brings a small metallic object, such as a key or a perforated sheet of metal, in front of the screen where the N-rays impinge upon it. The shadow of the object is then clearly seen on the screen. On moving it toward that part of the screen which is not exposed to the rays, the outline becomes dim and indefinite. On moving the object to and fro over the screen, the transition from the portion illuminated by N-rays to the portion not so illuminated is clearly marked. On looking at the screen in a tangential direction the phenomena are reversed.—R. Blondlot, Comptes Rendus, March 14, 1904.

ATMOSPHERIC RADIO-ACTIVITY IN HIGH LATITUDES.—G. C. Simpson has obtained some remarkably high values for the radio-activity induced by the atmosphere in the extreme north of Norway, at Karasjoh. He used the method described by Elster and Geitel. A wire was stretched between an insulator in the open and another in a room. The part exposed to the open air, 10 meters long, could be detached from the rest. The wire was charged to a negative potential by means of a small influence machine, and the potential of the wire was regulated by a variable resistance made of a piece of ebonite with a pencil line drawn on it. The potential was maintained at about 2,250 volts. The wire after being charged for two hours was wrapped round a cylinder of wire netting and its radio-activity determined by means of a dissipation electrometer. The radio-activity was estimated by the arbitrary unit devised by Elster and Geitel, unit radio-activity being possessed by the air when, after a two hours' exposure, a meter of the wire reduces the potential of the dissipation cylinder by 1 volt in one hour. The mean value of the radio-activity at Wolfenbüttel in 1902 was 18.6, the extreme values being 64 and 4. The numbers for Karasjoh are very much higher than the corresponding ones for Germany, the mean for the month being 102, which is nearly six times as great as the German mean (for the year); and the highest value, 432, being nearly seven times greater than the German

* Compiled by E. E. Fournier d'Albe in the Electrician.

highest. There is a marked daily period. The maximum falls in the evening, there being little difference between the morning and afternoon means. Not only is the mean value greatest for the evening, but the absolute maximum falls in the evening each week, and on 13 out of 22 days on which three observations were taken the evening values were the greatest. There is no direct relation between the radio-activity and the potential gradient. There does not appear to be any close connection between the aurora and the radio-activity, the greatest value of the radio-activity having been obtained when no aurora was visible. During the whole time these observations were being taken the sun did not rise above the horizon. The place of observation is 140 meters above sea level. The ground for 100 miles round is hard frozen to a great depth and covered with a coating of snow the average depth of which is over two feet. Sudden changes in radio-activity are sometimes observed to take place, as, for example, on December 17, when with a rising barometer the activity rose for a few hours from the low value of 66 to the exceptionally high one of 384. There is some difficulty in reconciling these observations with Elster and Geitel's view that the activity is entirely due to a diffusion of a radio-active emanation from the soil.—G. C. Simpson, Proc. Roy. Soc., March 13, 1904.

Electric Resistance at Low Temperatures.—J. Dewar has investigated the resistance of a number of metals down to the boiling point of hydrogen, which he has shown by means of the hydrogen and helium gas thermometer to lie at —252.5 deg. He arrives at the remarkable conclusion that the connection between resistance and absolute temperature in metals is not represented by a parabola having its vortex at the origin of co-ordinates, but by a curve resembling the sign *f*, and having asymptotes at certain values of the resistance, so that the resistivity of a metal can never exceed nor fall short of a certain amount. The magnetic metals present the most striking curves, being at first sight quite unlike any of the others. But on closer inspection it is found that this is not so, and, in fact, they give the clue to the general connection between resistance and temperature in metals. The magnetic metals and gold are found to have negative values of Callendar's co-efficient δ. Now, on examining the curves for the other metals, they are all found to be concave toward the axis of temperature for the arcs extending from the boiling point of water, through the freezing point, down to the boiling point of oxygen, while below the boiling point of oxygen these curves are convex to the axis. On the other hand, gold and the magnetic metals are already convex to this axis from the boiling point of water to the lowest temperature reached. It is clear that in no case can anything parabolic connect resistances and temperatures ranging from the boiling point of water to that of hydrogen. Just as we seek for a circle of curvature at any point of a curve, so in the present case we may, at a point or over a short range of the curve, seek for an approximate parabola, but any such parabola will be of little or no use for extrapolation. The alloys show a very slight slope in comparison with the pure metals. Of the latter, gold and silver are the most suitable for thermometry, since their temperature curves are nearly straight lines.—J. Dewar, Proc. Roy. Soc., March 10, 1904.

Velocity of Light in a Magnetic Field.—Several investigations have been undertaken to determine the nature of the Faraday effect. The kinematical explanation of the rotation of the plane of polarization in natural rotary substances by the assumption of two oppositely polarized circular components which travel with different velocities has led many investigators to a similar explanation in the case of the magnetic rotation of the plane of polarization. Such investigations have been made by Righi, Brace, and Morley and Miller. In every case the method has been to note the shifting of the interference bands formed by the divided portions of the same beam, one portion of which has traversed a medium in a magnetic field. The observations have hitherto been unsuccessful, but J. Mills has now obtained a definite effect by a modification of the apparatus made by Morley and Miller, in which a tube of carbon bisulphide, surrounded by a magnetizing coil, is placed in the path of each ray of a Michelson interferometer. In the new arrangement, the light was passed through a quarter-wave plate after leaving the Nicol, and the chance of a shifting of the bands due to any mechanical cause was entirely eliminated by substituting for the single quarter-wave plate a Bravais double plate giving right-handed circularly polarized light in one-half of the field and left-handed in the other. Thus, with the same current as before, an effect of four times the magnitude was to be expected. A distinct shifting of the fringes was noticed, and this shifting increased with the current. By interposing a rheostat in the system the current could be gradually increased until the shifting amounted to a full band—that is, until the fringes again coincided. The current was then about 13 amperes, and the corresponding difference of phase of the two circular components was 368 deg. A shifting of four bands was noticed for a current of some 52 amperes, but the heating effects of such a large current made it impossible to obtain a set of readings for that displacement with the same degree of accuracy as was possible in the preceding sets. The author was unable to detect any asymmetry in the amount of acceleration of one component as compared to the corresponding retardation in the other.—J. Mills, Phys. Review, February, 1904.

ENGINEERING NOTES.

Mr. Dugald Clerk, in a recent statement, said that in England there had been produced, altogether, nearly 100,000 internal combustion engines of an average of 20 horse-power.

It is estimated that the United States Steel Corporation owns iron ore beds to the extent of 750,000,000 tons. This includes all ore property owned or controlled by the corporation. The total output of its mines in the Lake Superior region in 1902 was 16,063,-179 tons as compared with 15,363,355 tons in 1903.

Large coal piers with coal-handling machinery are being built at Milwaukee, Wis., some of these being entirely new, while others are extensions of existing piers. One of the largest is 700 feet long and 400 feet wide, being adapted for the storage as well as the handling of coal. In connection with these piers improvements will be made to the inner harbor to enable large coal steamers to reach the piers without difficulty.

According to the Engineer, the quantity of water required at the ordinary temperature of 60 deg. F. inlet, and 150 deg. outlet, to keep the cylinders of gas engines cool is 4.5 to 5 gallons per indicated horse-power-hour. The jacket pipe should be from 1 to 2 inches diameter for engines up to 20 horse-power, while for larger engines the sizes are generally 2 to 3 inches for the inlet and 2.5 to 3.5 for the outlet. Tanks for circulating the water are generally made with a capacity for furnishing 20 to 30 gallons per indicated horse-power.

Another East River Tunnel at New York seems probable, but it will be for gas mains, like the only tunnel now under the river, and not for passengers, says Engineering Record. Just what the project actually is remains indefinite to those not close to the Consolidated Gas Company, but it is understood that it contemplates a tunnel from Lawrence Point, Astoria, to East 110th Street, Manhattan. A commission to condemn city and State property for the purpose was appointed early last month. The property of the gas company in Manhattan is very valuable, and it has been recognized generally for some time that sooner or later high taxes and other causes would compel the company to give up its gas works in the borough, and pipe gas through tunnels from huge plants on Long Island.

The electric locomotive designed by Mr. B. J. Arnold, president of the American Institute of Electrical Engineers, was tested on the Michigan Suburban line near Lansing with complete success. The main idea of this design was taken up about five years ago and developed carefully. An experimental locomotive was built and was all ready for test when it was destroyed by a fire in the car shops where it was kept. It was the first car equipped with alternating current motors, and the successful trials last week prove that had it not been burned it would have established beyond question Mr. Arnold's rank as the pioneer in this new departure which is now receiving so much attention. The equipment tested recently is largely that of the first car, repaired so far as possible. A speed of 25 miles an hour was reached during the run. The current was at about 6,000 volts. The successful outcome of this preliminary run is a subject on which the inventor will receive hearty congratulations. He was the first to enter the field of alternating-current car equipment and carried on his work without assistance from any of the great manufacturing companies. Whether his system will prove the most satisfactory remains to be determined, but the successful outcome of his experimental work conducted in the face of serious obstacles is as gratifying to his friends as to himself.—Engineering Record.

A dry-stone retaining wall on the Albula Railway, Switzerland, built in the spring of 1902, gave trouble by slipping and was reinforced in an interesting way, described recently in The Engineer. The wall was founded on shallow earth overlying steeply sloping and rather loose rock; and in several places cut just a little into the loose surface rock. Settlement was anticipated, and so the wall was built a foot higher than the intended level of its top. Several slips occurred during construction, attributed to the water flowing along the surface of the rock, and soon after the wall was finished it was observed to be creeping down and bulging out. In November the top of the wall was rebuilt. It passed the winter well, but the spring thaws and rains caused a renewal of the movement, at a rate of ½ inch to 1 inch per day. At the same time the wall bulged badly in places and assumed a stronger batter than it had when built. As this portion of the railway was in use, it was necessary to do something to prevent the failure of the wall. To give the dry-stone wall a secure foothold, as rapidly as possible a number of shafts were sunk down in front of it to reach the rock, and pillars of masonry made in quick-setting cement mortar were built up under the wall base, and also some way up in front of its face, being bonded into it, as well as possible to stiffen it against the bulging tendency. The buttresses of masonry were anchored into the firmer strata of the rock. The work, which had to be carried out with great caution so as to avoid any breakdown of the wall, was done in the course of three weeks, and gave satisfaction, as no further settlement was observed. The masonry buttresses had to be taken down some 23 feet below the foundation of the wall, which settled as a maximum about 4 feet, at the same time moving 1.3 feet outward.—Engineering Record.

ELECTRICAL NOTES.

F. Loppé arrives at the conclusion that the maximum mass-capacity of a lead cell is 28.1 ampere-hours per kilogramme, the watt-hour capacity being 53.39 per kilogramme. This is deduced by assuming the actual capacity to be two-thirds the theoretical total, so that per ampere-hour the active material will weigh 6.69 grammes and 5.79 for positive and negative active material respectively. From the Automobile Club de France trials of 1899 the weight of support is taken as 20 per cent of the active material, so that the plates together will weigh 8.14 + 7.24 = 15.38 grammes per ampere-hour, and the plate capacity therefore is 65 ampere-hours per kilogramme. The weight of electrolyte of density 1.285 is taken as 15.55 grammes, and the weight of jar and connections (15 per cent) 4.64 grammes, giving a total weight of cell of 35.57 grammes per ampere-hour.

A remarkable performance of an electric automobile was recorded in a recent issue of the Electrical Review. The machine covered the distance between Providence and Boston, on one charge, in 3½ hours, at about the rate of 15 miles an hour. The trip was made without accident, and the hill climbing done easily. Three consecutive hills, a distance of 1¼ to 1½ miles, were covered in 10½ minutes. The amperage rose to 65 and on the heaviest part of the incline to 76 for about one-half minute on each hill. The average demand for the hills was from 50 to 55 amperes, the average on the level from 22 to 25. The battery stood at two volts per cell at the end of the trip, so that there were probably 15 or 20 miles left. The weight of the battery of 42 cells is 1,219 pounds, and of the battery and carriage together a trifle less than 2,000 pounds.

An interesting trial trip was recently made over the Michigan Suburban Railway at Lansing, Mich., with a car fitted with the Arnold electro-pneumatic motor. The object was to determine the control of the system and the taking of current from the trolley at 6,000 volts. The car at times attained a speed of 25 miles per hour, and no difficulty at all was experienced even at this speed in taking current from the trolley. Mr. B. J. Arnold, who was at the trial, expressed himself entirely satisfied with the control which enabled speeds from the lowest to synchronism to be maintained, and was very satisfactory in retarding and accelerating. The system was completed about two years ago, but owing to a number of delays its trial has had to be deferred. Even at this date the trial trip back and forth over eight miles of line is probably the first case of single-phase traction over such a distance.

An article in the Elektrotechnische Zeitschrift of August 18 contains the results of a long series of experiments carried out by Prof. Slaby. The experiments deal with various important points connected with the tuning of transmitters, and afford a test of the value in practice of the formulæ available for the capacity and self-inductance of wires. The effect of neighboring earthed objects on the capacity of a wire was investigated by measuring by a telephone bridge-method the capacity of a 10-meter (33 feet) length of wire held horizontally at varied distances above floors of different kinds. Thus at a height of 1 meter above a zinc-covered floor, or above a wooden floor, the measured capacity was some 20 per cent greater than the value calculated by the simple formula for straight wires; but with a similar elevation above an asphalt pavement the error was only about 6 per cent. At heights greater than 2 meters the ordinary formula is, however, accurate enough; and a modified formula gives values for capacity and for wave-length agreeing well with all the experiments. In some of these observations the effect of damp weather was noticeable, since it increased the observed wave-length somewhat, probably because the capacity of the wire was increased by the presence of water in the dielectric. A different set of experiments was intended to decide whether the electric or magnetic portion of the electromagnetic wave plays the greater part in distance transmission. Here the apparatus was so arranged that either a potential loop or a current loop of the transmitter, as desired, could be put nearest the receiving circuit. Prof. Slaby found a difference approaching 40 per cent in favor of the magnetic effect, but he used distances of only 3 meters (9.8 feet). From this the author draws the conclusion that in fixing a wireless telegraph station it is most important to give free play to the circles of magnetic force expanding from the current loop at the bottom of the air-wire. Still another group of experiments examines the effect on capacity and wave-length of using as a sender a bundle of wires arranged parallel to one another or in the form of a cone. With equal parallel wires, spaced at distances of a meter or more, the wave-length is practically the same as with one of the wires, while the energy of charging is increased in proportion to the number of wires; with a closer arrangement of the wires the energy of charging is greatly diminished. With the conical arrangement of wires the energy of charging was found to be smaller than with the corresponding parallel arrangement. Prof. Slaby has further investigated the effect on the rate of radiation from a given air-wire system of introducing inductance coils at the lower end of the air-wire for tuning purposes, the principal measurement being made by placing a hot wire ammeter between the air-wire system and the added inductance. His results show, he says, that such a process of lengthening the wave is accompanied by diminution in the amount of energy radiated.

SCIENCE NOTES.

A specimen of the resin of *Hopea odorata* from Burma, examined at the Imperial Institute, was found to have the characters of a dammar resin; it is known as "rock dammar" in Indian commerce. It occurs in irregular yellow tears, with a brilliant irregular fracture, and a slight aromatic odor. It melts at 115 deg. C., and yields 0.56 per cent of ash. Its acid value is 31.5, and ester value 5.6. It is entirely soluble in turpentine, and partially so in alcohol.

An estimation of argon in atmospheric air has been made by H. Moissan (Comptes Rendus). The author, after referring to the various attempts to estimate the quantity of argon in air, points out the advantage of using metallic calcium for absorbing the oxygen and nitrogen, and also describes the method of securing uniform samples of moist air, the arrangements and precautions being detailed. A table is then given showing the amount of argon present in samples collected at different places in various parts of the world. The lowest value, 0.9305 per cent, was obtained in Martinique, and the highest, 0.9492 per cent, on the Atlantic Ocean, but no other value is higher than 0.9385 (Vienna); the values for Mont Blanc samples (4,810 m.) are practically the same as for Paris, London, and Berlin (about 0.9327, mean).

The cause of the nebulosity around Nova Persei is discussed by F. W. Very (Amer. Journ. Sci.). The author takes up various hypotheses to account for the nebulosity around the Nova, and considers that the following one only can be possible in view of the known facts, namely, the actual movement of diamagnetic ions under the control of magneto-electric impulses emanating from the star and following the lines of magnetic force. The light may be produced by the phosphorescence of dark matter previously existing in the dark space, and made luminous by colliding ions, or the moving ions may themselves be luminous. The author considers the latter condition more probable, but points out that only spectroscopic evidence can decide which of the two conditions obtains.

An ingenious fraud, consisting in the treatment of the seeds of a species of *Pisum* or *Lathyrus* to resemble black pepper fruit, is laid bare by E. Collin. This false pepper, which is known as "erviop"—a word which is merely an anagram of "poivre"—is skillfully doctored to impart to the naturally tasteless seeds a fictitious acridity, apparently by soaking them in an aqueous decoction of capsicum; the black color is obtained by treatment with a weak solution of an iron salt, which acting on the tannin in the integument, imparts the desired shade. Ground "erviop" is merely a mixture of these ground peas with powdered capsicum, often containing, as well, powdered olive stones. It is stated that when the whole "erviop" is mixed with black pepper it is not readily detected by a cursory examination. The histological characters, however, which are illustrated in the note, are, of course, totally distinct from those of genuine pepper.

According to Dr. W Volz, who has recently been traveling in the country, the two banks of the Lematang River in the Palembang district of Sumatra are respectively inhabited by different species of long-armed apes, or gibbons. On the west bank is found the siamang (*Hylobates syndactylus*), while the country to the east of the river is the home of the agile gibbon, or wau-wau (*H. agilis*). It is not necessary to capture, or even to see, specimens of the two species in order to satisfy oneself as to their limitations, for they may be readily distinguished by their cries, the siamang calling in a single note, whereas the cry of the wau-wau forms two notes. The remarkable thing about their distribution in Palembang is that the two species are found in company throughout the rest of Sumatra; and even in Palembang itself they inhabit the mountain districts, where the river is so narrow that they could easily leap over it, and yet they keep to the opposite banks.

According to Ernst A. Sjostedt in a paper read before the Canadian Mining Institute, the manufacture of sulphuric acid from pyrrhotite has been successfully accomplished at Sault Ste. Marie. The ore (from Sudbury) contains 15 to 20 per cent sulphur, 1 to 3 per cent nickel, and 0.5 to 2 per cent copper. The ore is sorted in two classes, one high in copper and low in sulphur, the other low in copper and high in sulphur. The former is smelted to matte in the ordinary way; the latter is sent to the acid plant. It averages about 28 per cent S, 3 per cent Ni, 0.5 per cent Cu, and 50 per cent Fe. The roasting is done in a modification of the Herreshoff furnace, the external cylindrical form being abandoned and four shafts constructed in a block, loss of heat by radiation being thus reduced. In this way, and with other means to conserve heat, designed in accordance with good engineering practice, satisfactory results have been obtained. The furnaces are constructed in muffle-form, arranged for gas-firing, but improvements in the details and increase in experience enabled that to be dispensed with, and ore as low as 20 to 25 per cent S has been burned down to 1 to 3 per cent S, producing a gas with 6 to 10 per cent SO_2, without the use of any extraneous fuel. The plant comprises four blocks of kilns with an aggregate capacity of 40 tons of ore per day, and up to the time of writing had burned 10,000 tons of pyrrhotite and 3,000 tons of pyrites. The experience is very valuable, showing how a poor sulphur ore can be almost completely burned without extraneous fuel when proper means are taken to avoid loss of heat in excess air, by radiation and otherwise.

THE Scientific American Supplement.

PUBLISHED WEEKLY.

Terms of Subscription, $5 a year.

Sent by mail, postage prepaid, to subscribers in any part of the United States or Canada. Six dollars a year, sent, prepaid, to any foreign country.

All the back numbers of THE SUPPLEMENT, from the commencement, January 1, 1876, can be had. Price, 10 cents each.

All the back volumes of THE SUPPLEMENT can likewise be supplied. Two volumes are issued yearly. Price of each volume, $2.50 stitched in paper, or $3.50 bound in stiff covers.

COMBINED RATES.—One copy of SCIENTIFIC AMERICAN and one copy of SCIENTIFIC AMERICAN SUPPLEMENT, one year, postpaid, $7.00.

A liberal discount to booksellers, news agents, and canvassers.

MUNN & CO., Publishers,
361 Broadway, New York, N. Y.

TABLE OF CONTENTS.