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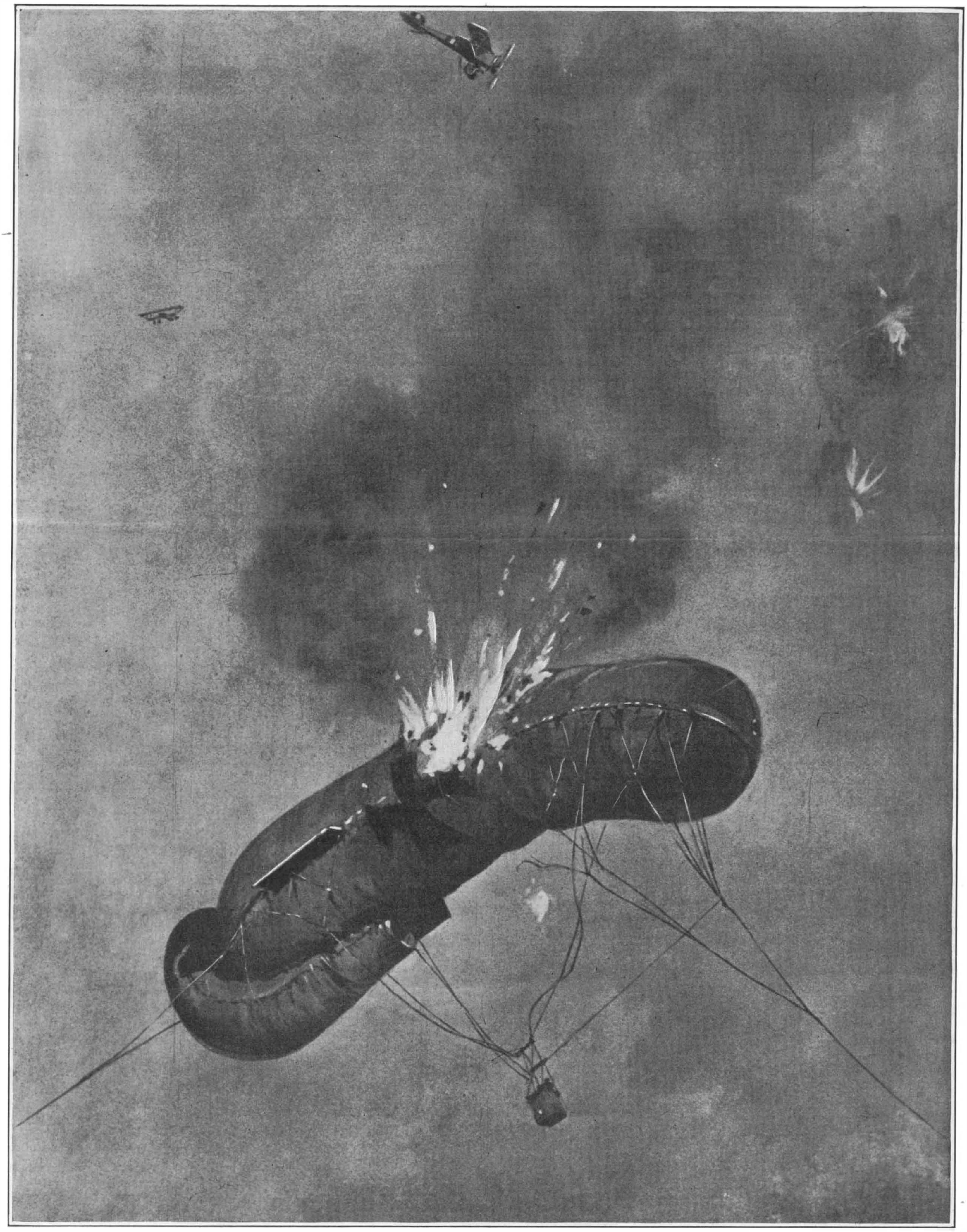


From The Illustrated London News

An anchored kite or "sausage" balloon destroyed by bombs dropped on it from aeroplanes.

AERONAUTICS IN THE GREAT WAR.—[See page 216.]

The Relation of Muscular Activity to the Mental Process*

The Energy That Directs the Movements That Represent Consciousness

By George Van N. Dearborn, A. M. (Harv.) M. D., Ph. D. (Col.)

To adequately develop the relations of muscle to the mental process would require a destructive criticism of the widely accepted notion that the nervous system, and especially the brain-cortex, is the sole physical basis of consciousness. The burden of proving such a thesis rests on those who accept it, and as a student of both the mental process and of the nature of protoplasm, I, for one, see no reason to accept this hereditary *ex cathedra* supposition. I wish here only to point out then, partially, the fitness of muscle, e. g., to correlate in part the ever-amazing inherent tide we know as consciousness.

As all propositions relating to psychological correlation must be, for the present at least, analogical in a measure, those that follow are so, but they also are inductive, and are based on the latest facts and ideas of physiology. They have but little sympathy, indeed, with the apotheosis of the nervous system, now popular, or with even a modification of the notion that the soul has its (rather uneasy) seat in the pineal gland. To those who realize the almost perfect unification of the bodily tissues, such a view is unlikely. This principle of localization will do for urine, for saliva, for bile, but not for body heat, for movement, etc. Above all, it will not suffice for consciousness, unless indeed consciousness really be a secretion—and we, every one of us, know better than that. Among the tissues and organs of the body, it is our privilege to inquire then what muscle (muscle-protoplasm unified largely by the nerves into a single and always vital mechanism) has to do with mind.

We cannot stop in this place to discuss the criteria of correlation *a priori*. Of the protoplasmic nature of muscle and its intimate structure it is important only to note that by its intricate chemical composition, and by its consequent elaborate metabolism, muscle is amply adequate as a correlate of the mental process. No other bodily tissue has more complexity either in its molecules, or in the arrangement of these molecules into cells and fibers. If subtlety of metabolism or intricacy of structure be criteria of a physical basis for consciousness, we can probably find in muscle the maximum of each. Under such conditions we might reasonably expect to find, furthermore, a unique variety of forms of energy, and among them, perhaps, several potential energies which might most closely represent the experience we know as mind.

CONSISTENT MOTION CHARACTERIZES LIFE.

A criterion of concomitance, perhaps more likely than these just mentioned, exists in the category of motion or movement, and attention must be directed to this for a moment. If one thing more than another characterizes life and its two aspects alike (the mental process and the phenomena of protoplasm), that thing is consistent motion. This is an irreversible time-series with its termini hidden from us, but with its actual process the most obvious of all our experiences. Unlike other forms of human protoplasm (excepting leucocytes and cilia), muscle has two sorts of movement: the molecular movements common to all matter (but at their maximum in organic substance), and mechanical or molar movement.

Using its end-products, carbon dioxide and nitrogen, as the gauge of the metabolism of muscle, we find it the most active of all the tissues. Muscle will absorb more oxygen and give out more carbon dioxide and more heat in doing so, than any other tissue per gramme of weight. From one strongly defensible viewpoint this fact is in itself important, since the liberation of energy seems the closest possible correlate of the mental process in its various degrees of consciousness. But we will pass that for the other certainly much less debatable form of motion, i. e., gross, mechanical, or molar movement (contraction).

MUSCULAR TISSUE ALWAYS ACTIVE.

Recent physiological work on muscle has emphasized how literally this tissue may be said to be always active in a mechanical as well as in a molecular, metabolic way. This molar activity is expressed as the "tone" of muscle. This tone (or tonus) seems characteristic of life and departs only at death. It is essentially a useful partial contraction varying back and forth in a sort of balance, now stronger, now weaker, as conditions require. Very recent work makes it likely that every bit of muscle tissue, whether "striated" or "unstriated" (distinctions which tend to disappear), has two sorts of contraction: its proper, relatively quick movement, superimposed and based on this slow and rythmic tonal beat. This tonal contraction has been studied and described in physiological laboratories where the term consciousness expresses scarcely more than a useless epiphenomenon. But the psychologists long ago (in the kinesthetic theory of feeling) demonstrated from the "mental side of the curve" just this same thing, practically, in muscle tissue. With the proper apparatus it is easy to demonstrate that in every portion of the body, muscle-tissue by its activity represents every feeling-tone strong enough to be considered as such. These two facts concerning the universality of muscle action strikingly corroborate each other and give to each an explanation lacking without the other. From the purely myological side one finds all muscle always contracting, balancing actively back and forth; from the psychological side we all see feeling to be universally an aspect of consciousness, and always accompanied by somatic movements all over the body. Do not these help explain each other and at the same time unify for us still further the dural aspects, body and mind?

MUSCLES CONCEIVED AS SEPARATE PIECES OF APPARATUS.

It is easy, especially for the psychologist, perhaps, to think of the muscles as separate pieces of apparatus like pistons or other shortening and lengthening devices, or that they are at least like tools of rubber reacting after being mechanically stretched. Such a mode of conceiving muscle is in fact a natural corollary of the anatomy of muscles as found in the books of a few years back. As seen from the outside, the muscles are just this—separate masses of flesh which somehow or other shorten and draw towards each other whatever holds their ends. Subjectively and physiologically viewed, how different muscles seem! One of the most marvelous of the marvels of the organism is the muscle fiber, both in the chemistry and the physics of its living matter. No one knows surely how it works, much less its essential structure, but the perfect unification and functional correlation of its activity, despite the relative separateness of its muscle-bundles, every observer understands.

But the gross voluntary muscles of the bones are only the most conspicuous of the outer muscles of the body. Muscle constitutes almost or quite half the mass of the organism and its all pervasiveness few psychologists have stopped to consider. There are more than 600 striated or "voluntary" muscles, and everywhere else in the body (save in the bones, in the nervous system, and in the alveoli of certain glands) smooth muscle tissue is found. All up and down the blood and lymph vessels in almost every minute part of the body, up and down the whole alimentary canal and the ducts and glands attached to it, up and down the whole respiratory system, and the excretory organs and the reproductive organs, in the spleen, in the skin, and in many of the sense organs, smooth or unstriated muscle maintains unceasingly its tonal and occasional contracting. Thus one properly thinks of the muscles as all-pervading tissues of living matter working continually and everywhere—not by any means as if made up of separate gross parts, inanimate tools which some obscure and hereditary notion of will hidden in a brain cortex uses much as a mason handles a wooden and steel trowel. In psychology especially, muscle should be thought of as a reticulum, a semi-liquid vital tissue, part of whose function in the general life is to conduct the all important movements of the body parallel somehow to the movements in the mental series. This widely permeating (fibrillar?) network of muscle fibers is unified and made practically a single organ by the same means by which the other tissues are unified, probably by protoplasmic bridges and certainly by currents of the blood and lymph and the all-bridging nervous system. More and more, the various functional systems of the body unified by these three means at least, are seen to be only inseparable parts of a perfect continuum, both as to use and structure. Muscle surely partakes in that basal generalization that mind no less than life inheres only in unifications. Arnold has lately made this concept current in his expression, "Motion-as-a-whole."

How autonomous muscle-tissue is, many recent researches have plainly shown. One of the latest at hand is that reported by Wintrebert, who demonstrates in a new way how independent of nerve the contracility of muscle is, proving that this sort of protoplasm performs its inherent function before the nerves have grown into it from the developing nervous centers. Kurdinouski and Franz, separately, offer similar evidence from an entirely different direction, while Bethe, Marinesco, Vermes, Kolmer, Michotte, and especially Dogiel, Loudon and Ramon y Cajal, each by a separate research, using for the most part methods quite new, publish recent work tending to establish yet more firmly the fibrillar nature of the nervous system—as a vast conductive mesh connecting functions outside itself. Long since, Sir Michael Foster, notable among physiologists for the breadth of his vision and the excellence of his judgment, called muscle "the master tissue of the body." How can we continue to ignore all these myopsychic relations? The mere wires of an electric system are not its essential part.

THE WILL NOT SEATED IN THE BRAIN.

One no longer, surely, thinks of the "will" as seated in the brain, causing the muscles to contract by its own iniative and through its own agency. In no sense does muscle, in the hierarchy of the tissues, own any inferiority to the nerves. The brain, probably the cerebellum, coördinates the movements and, in case of the voluntary muscles, directs them on the same basis that some of the glands provide them with metabolic enzymes, the intestines with food, the blood with commissary and sewerage service, and the lungs with oxygen. But the muscles, like the glands, the intestines and the lungs, are living protoplasm and we have the right to suppose serve the brain no more than the brain serves them. Each is but a special differentiation of one living substance like the rest of material force and matter, containing no essential inherent tendency to centrality.

If, as we may, we define the personality—the individual—as a center of purposes, we have a basis for a twofold division of the movements which fulfill its will. On the one hand, primary in philosophic importance, are the acts which directly help the evolution of the world, however little any one act may count in this direction. These are the "voluntary" movements and they are made only with the greater or less attentive effort of consciousness. Beneath these and vegetative in nature, as Starr calls them, are the reflex movements, mostly of the unstriated muscles; these latter reflex movements make the voluntary movements possible. Scattered equally through both kinds of muscle are multitudes of both afferent and efferent end-organs of many kinds, that properly speaking are parts of the nervous system.

CO-ORDINATION OF THE VARIOUS FIBERS.

Through these is effected the coördination of the various fibers to each other and the organic needs. By what right or reason can it be presumed that these common end-organs, and their nerve fibers and centers "represent consciousness" in case of the voluntary muscles and not in case of the involuntary or reflex muscles? One searches in vain the known facts concerning the paths and centers of the nervous system for any essential differences in the paths or in the tracts devoted to these two kinds of movement, save that the voluntary muscle (because of its necessary connection with the "higher" coördinating centers?) is coördinated in the cortex of the cerebrum as well as in the cerebellum. Such double "representation" in the great neural connecting reticulum of the body may very well stand for a larger share in the *attentive* consciousness than belongs to the vegetative muscles, because more parts of the body are then involved. Many things, however, indicate that in those large parts of the varied mental process which we call subconsciousness the reflexly or automatically acting portions of the muscle tissue play a very large part. Conscious effort accompanies the coördination of the voluntary muscles, perhaps because the process is a relatively novel one each time, but the reflex muscles, often well-nigh automatic, normally act without drawing the actual attention of the subject. It must not because of that, however, be presumed that they count less in making up the fusion current of the fundamental subconscious aspects of mind.

Did time allow we should like here to consider in detail those most elaborate although unconscious manifestations with which we are all more or less familiar

*From the *American Physical Education Review.*

in imitation, in somnambulism, and in muscular automatism of many kinds. We should consider, too, some of those still obscure afferent (sensational) aspects of the muscles, especially in abnormal muscular conditions such as those of angina pectoris in the heart muscle, of colic or cramp in the hollow viscera or tubes, of the sensory visceral disturbances of hysteria and of paranoia. These derangements, purely muscular in origin, are just beginning to be technically understood in the subtle complexities of muscular composition or structure. Is any one really content to say that it is the brain protoplasm and not the muscle protoplasm that represents aberrations from the normal consciousness like these? And when, in direct sub-conscious imitation, a large group of the fibers of the muscle-reticulum act in a certain way, are you each quite satisfied to imagine, as did the revered Descartes, that a few grammes of protoplasm in the cerebral cortex knows it all, does it all, and represents withal what little of attentive consciousness appertains? And in the voluntary muscular efforts by which all that is new is accomplished, do muscular cunning and skill and cleverness count for nothing, and indeed mean nothing but a better brain? Is the subjective consciousness that accompanies the piano playing of a master pianist based wholly on his better sort of brain cortex (a layer of protoplasm similar to that of muscle and only three millimeters thick), without possible relation, save as to a set of tools, to the muscles which alone possess such perfect cunning, and do all the wondrous work? To me, for one, such a supposition seems not merely unlikely, as it is inherently absurd, but, what is of far more importance, it seems assuredly an impeding and gratuitous presumption which the balance of evidence emphatically rejects.

MARVELOUS STRUCTURE OF ANY MUSCULATURE.

Such are some of the considerations that arise in one's mind when one considers the marvelous structure of any musculature. They are obviously, in part, the reactionary products of revolt against what we have already called the unwarranted apotheosis of the nervous system, especially of its gray matter. The natural *a priori* presumption of the average child would be, it is likely, that the body in general is conscious, that all protoplasm is the basis of physical life. If we can escape such a conclusion, we do so only by a presumption. We may admit that the proof that all protoplasm is embued with consciousness is utterly unobtainable. We may have to think of this proof as so purely abstract and speculative that it lacks that criterion of utility which we always demand in our science. If this is so, there is a way of reconciliation.

We may claim, without fear of dispute, that the muscles furnish their quota of the energy of the afferent aspects of the nervous system. It is the movement in and of the muscles, tendons and joints that starts the kinesthetic and other cenesthetic impulses toward the centers. It is the stupendous maze of the central nervous system, on the other hand, that *coördinates* these multitudes of influences pushing into the gray matter. Our problem resolves itself then into a matter of definitions—as so often happens in science and philosophy.

CO-ORDINATION AND VITALITY THE BUSINESS OF NERVOUS ORGANIZATION.

No one would think of an isolated muscle or muscle-fabric even as possessing consciousness. It is only when this portion of muscle-protoplasm is part of an individual that it may be said to have feeling or any phase of mentality. The nervous system is the chief means of coördinating the muscles and other organs of the body. Coördination and vitality, as Morat usefully coins the word, is the sole business of the nervous organization. Without its integrating activities there could be no personality, no center of conscious or subconscious purposes. Associative memory, the ultimate biologic analysis of mind, could not persist and give the muscles and the epithelium, the bones and the connective tissues usefulness and a personality. In this sense, then, namely as a coördinator and integrator, the central nervous system is undeniably the basis of consciousness. Without it, or its equivalent, personal mentality were unthinkable, for in a chaos, purpose and the other attributes of personality do not inhere.

When, however, we trace to its source the *energy* that directs the movements that in turn represent the stream of consciousness and subconsciousness, we find that of all forms of protoplasm in our bodies none has a better claim to represent the mental process than has muscle.

Poker Explodes

A STEAM plant had occasion to use as a poker a 10-foot rod made of heavy tubing, one end of which had been hammered together, the other end being open. The open end was always thrust back into the coal pile after using with the result that some finely powdered coal found its way inside. It was decided, however, to close the other end also. The next time the poker was used to any extent there was a terrific explosion that tore the poker apart and hurled the fireman against the boiler. It was thought that a quantity of the powdered coal remained in the tube.—*Electrical World.*

Propeller Immersion and Efficiency

IT is not uncommon to hear the opinion expressed that a screw propeller attains higher efficiency when deeply immersed than when it operates near the surface, and for this reason it is sometimes suggested that submarines may attain better results when submerged than when running on the surface. In many vessels the idea has caused a greater vertical inclination to be given to propeller shafts than is desirable from other points of view. To expect increase of efficiency from mere increase of immersion is quite erroneous. There is no benefit from immersion alone, so long as the speed of slip imparted to the water by a propeller is less than the speed of flow to the screw, which can be produced by the combined pressures due to head of water and atmosphere, and there is no air drawing; indeed, it was pointed out in a paper read before the Institute of Marine Engineers in 1905 that analysis of trials of a number of destroyers carried out in smooth water showed that "the least immersion of the propellers gave the best results, both in speed and coal bill." This has also been found to be the case in vessels of other types. Taylor says in his book, "Speed and Power of Ships," "There is little doubt that, contrary to what is generally supposed, a propeller for smooth water work is more efficient the closer it is to the surface." This superiority is explained by the fact that a propeller near the surface gets more useful reaction from the wake of the ship than one more deeply immersed, for frictional, wave and steam-line wakes are all strongest near the surface. The wake in this region may be looked upon as existing not only in a layer round the hull of the ship, but also as a shallow stratum spread along the surface, widening as it goes aft. For this reason a propeller near the surface reaps greater advantage from the wake than one more deeply immersed, while at the same time there is a decided disadvantage in having shafts inclined downwards at the after end to any great extent, for it involves placing the shaft webbing at such an angle to the direction of advance that there is likely to be unnecessary resistance on this account. The disadvantage is aggravated at high speeds if the ship squats by the stern, as is generally the case. There is reason also to think that the propeller itself does not work so efficiently when the inclination of the center of shaft to the line of advance is considerable, for the slip angles of the blades vary to a greater or less degree, depending on position during rotation and degree of inclination of the shaft. There is no advantage from immersion to compensate for these disadvantages when a vessel is running in smooth water, but there is the practical consideration of possible racing when in a seaway, which leads many designers to give deep submergence to propellers, and it is a very important feature to bear in mind, apart from the question of efficiency, for the stresses on propeller shafting when a revolving propeller is alternately plunged into and lifted out of the water are very serious. The practice of deep submergence is therefore quite justified in many cases, but it is probable that the practice has given rise to a prevalent opinion that depth of immersion is desirable simply for reasons of efficiency. In discussing the effect of immersion we must therefore remember that all other considerations of efficiency may be subsidiary to that of preventing racing in a seaway for any particular service, but it is necessary for a proper understanding of the case that we ignore racing for the time and examine the conditions for smooth water conditions only.

Propulsive effect of a screw propeller is obtained by imparting to a body of water an absolute speed in the sternward direction. This is the fundamental condition, and it involves the necessity for a continuous supply of water to the propeller in order that the flow of feed may be steadily maintained. There are two conditions to consider which may modify speed of supply. If the propeller be partly immersed and the speed in feet per second imparted to the screw race be greater than $\sqrt{2gh}$, where h is the immersion in feet of any point on the blade, the effect which is known as air drawing is produced, for the water will not be able to flow quickly enough to the blades to supply their need, there will be direct access of the atmosphere to the blades, the pressure due to atmospheric head will be lost and efficiency very seriously impaired. Air drawing must not, however, be confused with cavitation, which is similar in appearance but totally dissimilar in character. Regarding the condition of partial immersion of propeller it may be remarked that no loss of efficiency is involved when part of the propeller is out of the water unless and until the speed of slip imparted to the race is greater than $\sqrt{2gh}$. There have been cases of ships running in smooth-water conditions, such as river and canal steamers, where a large diameter of propeller, only half immersed, has been deliberately adopted in order to act upon a larger column of water than is obtainable with a smaller propeller wholly immersed, and the results have been satisfactory. The conditions for a propeller so designed are analogous to those of a paddle float, for the speed at which water can flow to a float under the influence of gravity being $\sqrt{2gh}$ as before, it is only at a depth h below the water surface which equals $\frac{V^2}{2g}$ that the water will be able to keep in contact with the back of the float, and all parts above this height will be in contact with air, the water surface on the forward side of the float falls until a position of equilibrium is established. The ordinary condition for screw propellers is that of total immersion, and where there is no air-drawing the speed of flow available is that due to the combined pressure of water and atmosphere, being expressed by

$$v = \sqrt{2g(h+32)},$$

v being speed in feet per second, h the immersion in feet at any point, and 32 being taken as the equivalent height of water column which balances average atmospheric pressure. This additional head, although expressed in terms of water column, is due really to pressure of an air column, which is highly elastic and has little or no inertia, so that its effect is probably greater in proportion than that of an actual corresponding head of water. Whether this be so or not, it is evident that the head due to atmosphere is the larger part of the total head available to produce flow of water to the propeller, for the usual immersion is only a few feet. Any change of immersion must therefore have a relatively small effect upon the limiting pressure available. There seems no reason for the opinion that increase of immersion will result in increase of efficiency within the range of speeds of race, for which there is an uninterrupted supply of water to the propeller, but it naturally increases this range. Although the theoretical limit of speed is

$$\sqrt{2g(h+32)},$$

it is probable that the feed of solid water to the propeller becomes seriously impaired at a much lower speed. Whatever the actual speed at which the flow becomes discontinuous, the phenomenon which takes place is that which is known as "cavitation," and the point of commencing cavitation may be affected by immersion, for the speed at which more or less vacuous cavities are formed will be slightly advanced, but only slightly, for the velocity of flow due to atmospheric pressure is common to all immersions. It will thus be seen that "cavitation" and "air drawing" are totally different manifestations and are caused by different conditions.

Water is practically incompressible, and its density is not therefore affected by depth. The reaction of a propeller at 1 foot depth is the same as that at 10-foot depth, although the pressures are quite different. The same principle governs the amount of surface friction of a ship's hull. The friction per unit area at the water line is the same as that at the keel for the same distance from the bow. Calculations of skin friction depend only on the amount of surface and the length of plane, and not at all on depth of immersion, although the pressures at the water line and the keel are quite different. The controlling factor is incompressibility of water and constancy of its density. The distinction between pressure and density effects is one which seems to confuse beginners. It must therefore be realized that, regarded from the point of view of immersion alone, there is no increase of efficiency obtainable by increasing immersion. On the contrary, the evidence available shows that a greater efficiency is obtained near the surface than at a greater depth, because of increased hull efficiency, but where there are possibilities of air drawing and racing from pitching in a seaway it is essential that the propellers be deeply placed. If there is reason to fear cavitation it may also be desirable to increase immersion in order to raise the limiting rate of flow. These considerations are, however, apart from the suggestion that mere depth of immersion may result in higher efficiency, and unless they are factors in the design, there is no reason for striving after a deep position for the propellers.—*The Engineer.*

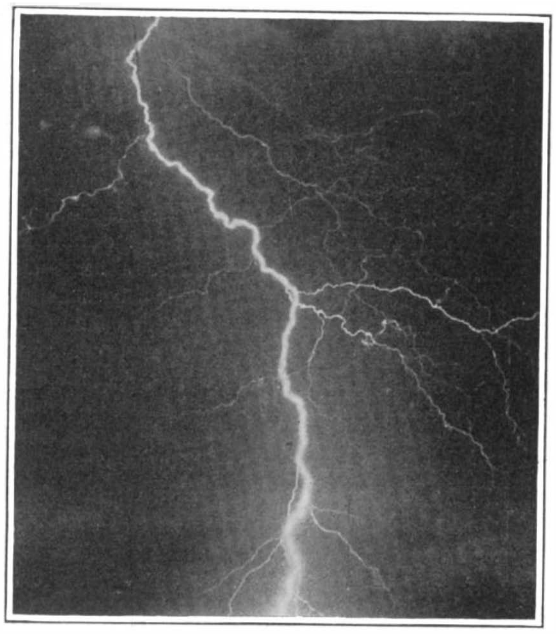


Fig. 1.

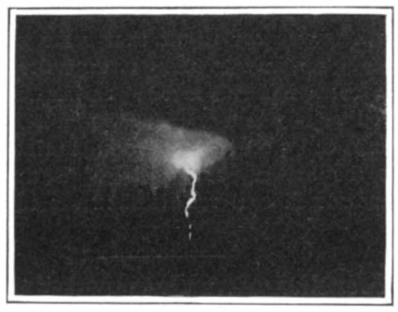


Fig. 3.

Actual photographs of lightning discharges taken by the writer. Figs. 1 and 2 show the familiar form of forked lightning of common occurrence, which is inevitably accompanied by heavy, crashing thunder. Fig. 3 shows an extremely heavy discharge from a cloud relatively near the earth; discharges like this produce a very heavy clap without the rattle common to the variety shown in the first two figures.

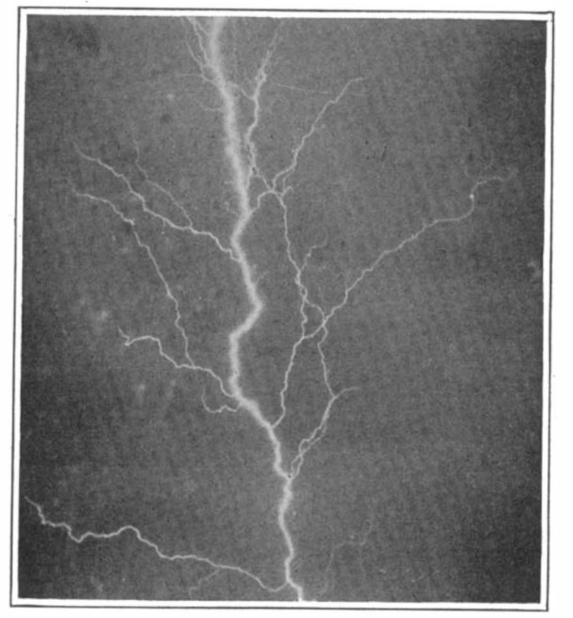


Fig. 2.

A New Explanation of Sound Phenomena

Accompanying Disruptive Electrical Discharges in Air a New Theory of Thunder

By B. F. Miessner

A CENTURY and a half ago our own brilliantiy versatile Benjamin Franklin first proved the electrical nature of lightning. His kite and key experiment, that famous classic in which he drew powerful electric sparks from the clouds and demonstrated all the effects of ordinary frictional electricity, gave such an impetus to scientific consideration of the then unexplained electrical phenomena and furnished such a firm foundation for further investigation that Electricity as Man's harnessed power has grown into a structure of tremendous proportions.

In order to understand the electricity of Nature we must first get an insight into the real mechanism of cloud electrification, and then proceed to the effects accompanying the sudden discharge of accumulated electrical energy.

Solids and liquids cannot be charged throughout their substance; if charged at all the electricity is on the surface. But gases and vapors, being composed of myriads of separate particles, can receive a bodily charge. The air in a room in which an electric machine is worked is afterward found charged.

The clouds are usualy charged more or less with electricity which is derived probably from evaporation going on at the earth's surface. That such action does accompany evaporation may be shown by throwing a few drops of copper sulphate into a hot platinum crucible; violent electrification results as they evaporate.

Closely connected with the electricity of evaporation is the atmospheric electricity always present in the atmosphere, and due at least in part to the evaporation going on over the oceans and other bodies of water. The minute particles of water floating in the air being better conductors than the air itself, become more highly charged. As they unite, due to the supersaturating influences of lowering temperatures, the strength of their charges increases.

Suppose eight small particles to join into one. That one will have eight times the quantity of electricity, but it will be distributed over an area much smaller than that of the original drops, and therefore, since the charge exists only on the surface, the potential is increased. The actual potential of the large glouble will be four times as high as the original potential of the separate particles. A mass of cloud may consist of such charged spheroids and its potential may gradually rise, therefore, by the coalescence of the drops; and the electrification at the lower surface of the cloud will become greater and greater, the surface of the earth beneath acting as a condensing plate, and becoming inductively charged with the opposite kind of electrification.

Presently the difference of potential becomes so great that the intervening strata of air give way under the strain, and a disruptive discharge takes place at the point where the air offers the least resistance. This lightning spark, which may be more than a mile in length, discharges only the electricity that has been accumulated at the surface of the cloud, and the other parts of the cloud will now react upon the discharged portion, producing internal attractions and internal discharges. The internal attractions thus set up account for the usual appearance of a thunder cloud, that is, a well-defined, flat-bottomed mass of cloud which appears at the top to be boiling or heaving up with continual movements.

Three kinds of lightning have been distinguished by Arago, a celebrated French astronomer and physicist:

(1) The zigzag flash or "forked lightning" of ordinary occurrence. The zigzag form is probably due either to the presence of solid particles in the air or to local electrification at certain points, making the crooked path the one of least resistance.

(2) "Sheet lightning," in which whole surfaces are lit up at once, is probably only the reflection on the clouds of a flash taking place at some other part of the sky hidden from view. It is often seen on the horizon at night, reflected from a storm too far away to produce audible thunder, and is then known as "summer" or "heat" lightning.

(3) "Globular lightning" in the form of balls of fire, which move along slowly and then burst with a sudden explosion. This form is very rare but must be admitted as a real phenomenon, though some accounts of it are greatly exaggerated. Similar effects on a small scale have sometimes been produced accidentally with electrical apparatus. Cavallo gives an account of a fireball slowly creeping up the brass wire of a large, highly-charged Leyden jar, and then exploding as it left the end and descended. Planté has observed similar but smaller globular discharges from his "rheostatic machine," charged by powerful secondary batteries.

So much for the purely electrical nature of lightning. Let us now proceed to a discussion of its effects and of the causes underlying them.

Analytical minds of Benjamin Franklin's day turned naturally to his new theory of the heavenly fire for an explanation of the violent explosions and other physical effects accompanying it. The fact that the electrical discharge, as one sees it, consists of an incandescent column or zigzag streak of incandescent air, led to the immediate conclusion that the extremely sudden and great rise in the temperature of the air in the spark causes it to expand suddenly and set up a very powerful wave of compression, and that this spreads out in all directions from the spark path as a center, followed immediately by a wave of rarefaction which the compression wave envelops. Further, that these two atmospheric disturbances spread out with a speed equal to the speed of propagation of sound waves, or one thousand and ninety feet per second, and upon striking the diaphragms of our ears, produce the effect which we recognize as the characteristic sound of thunder.

If the spark be straight and short as in Fig. 3 the observer will hear but one short, sharp clap. If its path be long and forked (see Figs. 1 and 2) he will hear the successive sounds one after the other with a peculiar rattle, and the echoes from other clouds will come rolling and rumbling in long afterward.

Oscillographic studies have proved conclusively that lightning discharges are oscillatory in nature, that is that they consist usually of several separate sparks passing alternately in opposite directions with extreme rapidity. The photographs shown in Figs. 1, 2, 4, 5 and 6 are of actual lightning discharges and were taken from the top of the Hotel Belmont in New York city looking toward Brooklyn. In Figs. 4 and 5 the separate sparks forming the discharge may be clearly seen as well as the decrease in their intensity. The frequency of the discharge sparks was in all probability quite low, corresponding to a long path of high inductance and a cloud of considerable area and capacity, thus giving a long wave length and relatively slow frequency. Due to the high velocity of the air the discharge path was carried toward the right and the succesive sparks in the discharge therefore appear in different positions.

There are other effects of lightning discharges besides sound; let us inquire into their nature.

The effect of a lightning flash when it strikes an imperfect conductor appears sometimes as a disruptive mechanical disintegration, as when the masonry of a chimney stack or church spire is overthrown, or a strong tree splintered, and sometimes as an effect of heat, as when wires and objects of metal in the path of the discharge are fused. The physiological effects are well known, the result being either instant death or severe burns when the stroke actually passes through the body. If it occurs not actually through the body but at a very short distance from it, currents of sufficient strength may be induced in the body to cause temporary loss of consciousness.

The previously mentioned theory of thunder lends itself easily enough to the explanation of these purely mechanical effects because the degree of compression of the air in the sound wave may well reach such proportions that they will act almost like a solid body moving at an equal velocity, at least near the source of the disturbance, where the effects are strongest.

That sound waves of this nature are capable of producing such marked mechanical effects may well be illustrated by the firing of large caliber guns. We will take a particular instance.

The wireless office aboard the United States battleship "South Carolina" is a wooden structure ten feet square and it is situated in the base of the after fire control tower. The distance to the muzzles of the nearest of the after 12-inch guns is about fifty feet. The outside walls consist of ordinary one-half inch flooring material; it has six windows of approximately 24 by 24 inches, and two 3 by 6 foot doors.

During battle practice it was necessary to reinstall the wireless apparatus in the battle station, which is situated below the protective deck, and behind the heavy side armor in the after distribution room.

To prevent the compression wave set up by the firing of the big guns from breaking in the window panes, the windows as well as the two doors were removed, so that all precautions looking to the avoidance of unequal distribution of pressure between the inside and the outside of the house might be taken.

The windows were set inside the office.

In spite of all these precautions several of the boards

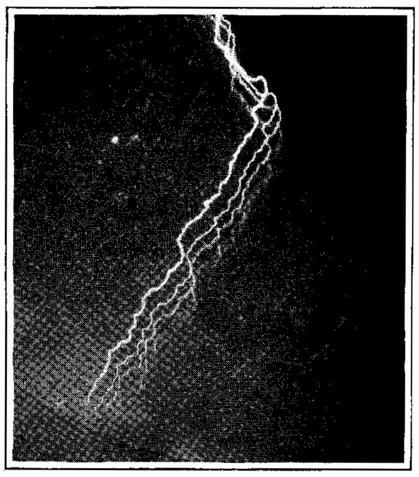


Fig. 4.

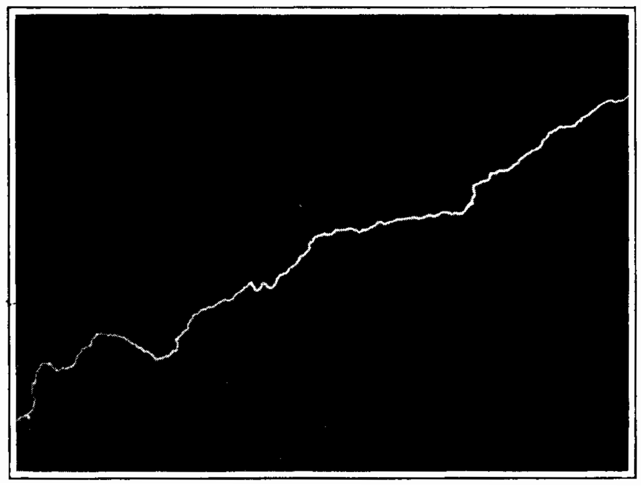


Fig. 5.

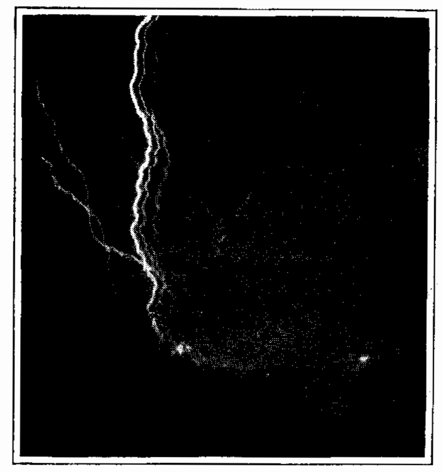


Fig. 6.

Figs. 4 and 5 show the separate sparks comprising a single discharge as explained. Fig. 6 shows the type of discharge which is very frequently unaccompanied by thunder.

on the outside of the house were found crushed in after the firing. The compression wave set up by the rapid expansion of the incandescent gases at the muzzles of the 12-inch guns fifty feet distant, acting almost like a solid mass traveling with a velocity of over a thousand feet per second, had crashed against the boards and produced the effect shown in the photograph (Fig. 7). The windows inside, which were not directly in the path of the advancing wave were unharmed.

Occasionally newspaper or magazine photographers who are permitted to observe the action of Uncle Sam's dreadnoughts in action disregard the instructions given them and approach too closely to the muzzles of the guns in the effort to photograph the discharge. On several occasions these men have been knocked over bodily when the guns were fired.

These illustrations serve merely to prove that some of the mechanical effects produced by lightning discharges, which many times are far more powerful than the explosions of the biggest guns, can without doubt be attributed to the compression waves set up by them. Other effects, such as the fusing of metals, are readily explained by the heating effects of the heavy currents passing through them.

Three facts of common observation lead one to make a somewhat deeper investigation into the present explanation of the causes of these diverse phenomena accompanying disruptive electrical discharges in air. These are:

1. Lightning is frequently unaccompanied by thunder.
2. The so-called heat lightning produces no audible sound.
3. The most violent lightning and thunder occurs during the progress of the downpour of rain and through that rain between cloud and earth.

These observations lead to the following very important question:

If the thunder and other mechanical effects are produced by the rapid expansion of the air due to the heat developed by the passage of the current through the resisting air (this in watts is equal to the product of current squared and the resistance through which it passes) why does this explanation not apply to every single case of lightning discharge? The present theory offers no answer to this query. There is nothing human or capricious about natural law. Occupy a lifetime if you will, throwing up a ball; is it necessary to state that it will return to earth every single time? Is it possible that the so-called law of thunder production is a fickle sort of an affair that at one time does one thing and at another time some other different thing? Hardly. Is it not on the other hand entirely within the bounds of reason to assume that every lightning spark, which, as we well know, does liberate considerable heat suddenly, should produce the sudden heating and expansion of the air and consequently the sound wave; that every spark should produce some sound, and that the intensity of that sound should vary with the intensity of the current discharge?

The observations cited tempt one to believe that the presence of *moisture* in the discharge path may in some intimate way be related to the sound waves produced. We might even boldly say that the *lack* of sufficient moisture, in the cases of those strokes unaccompanied by thunder, explains the lack of sound; and that the intensity of the sound given off is in some manner proportional to the density of the moisture in the discharge path as well as to the quantity of electrical energy liberated by the discharge.

In testing high tension insulators where a water spray is used to simulate rain conditions, the heaviness of the breaking-over spark increases with the density of the spray from a thin almost inaudible forked thread to a thick crashing discharge. And now we must advance another step in recognizing the possibility of a very definite relationship between the intensity of the sound and the moisture content of the air. Several well known facts point to such a relationship:

First, an electric current in passing through water will decompose it into its component parts, oxygen and hydrogen, one part by volume of the former to two parts of the latter.

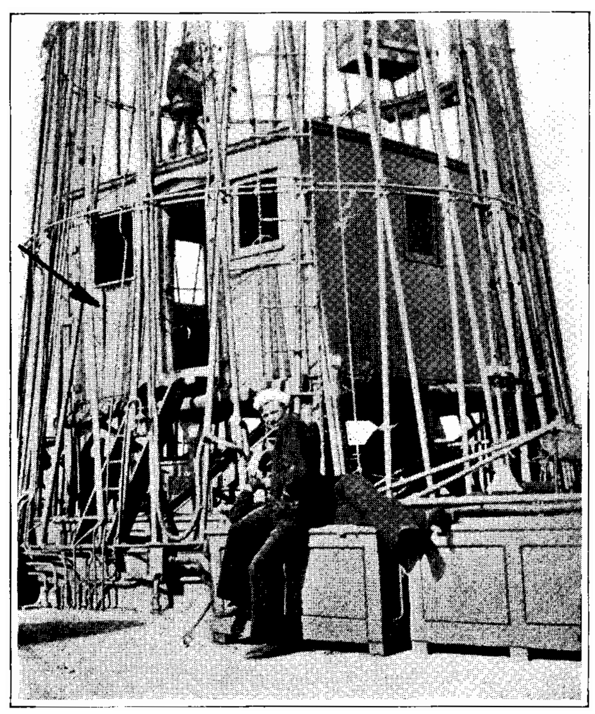


Fig. 7 shows the effect of compression waves set up by the firing of large caliber guns aboard ship; the arrow indicates where the walls of the wireless office were crushed in.

Second, water is decomposed into hydrogen and oxygen when heated to a temperature of about three thousand degrees Centigrade.

Third, oxygen and hydrogen, when mixed in the proportion obtained by a decomposition of water, form a very highly explosive mixture that can be set off by an electric spark. These facts form the nucleus of a new explanation of thunder, which, stated briefly and simply, is as follows:

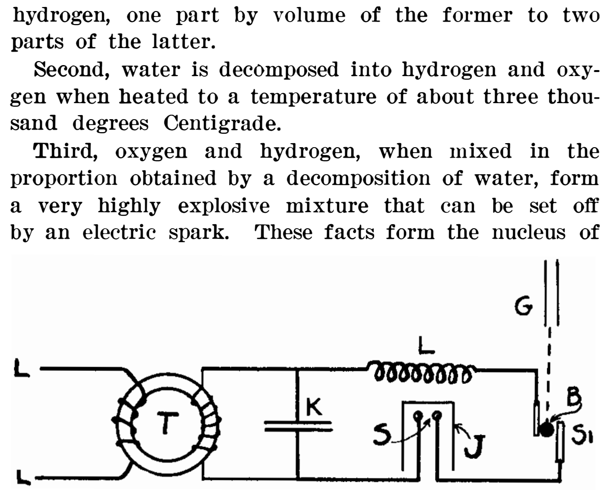


Fig. 8.—Diagram showing arrangement of apparatus for the experimental proof of the thunder explanation herein given.

Due partly to the electrolytic, partly to the purely thermal action of the discharge current, suspended water particles in its path are instantaneously decomposed into hydrogen and oxygen by the first spark of the series comprising the complete discharge. The explosive mixture thus formed is at once ignited by the second spark of the series, the original amount of water being produced when the gases recombine. If there are more than two sparks, four or six or eight, for example, the same cycle of actions is repeated for each pair. These separate explosions are heard as one loud crash. The strokes not accompanied by an explosion are those which, due to the quick damping action of a high resistance path, consist of but one spark, there being no second spark to ignite the explosive gas mixture produced by the first, or to the lack of sufficient moisture in the discharge path, in which case sufficient gas to produce an audible explosion would not be formed. The moisture is probably doubly effective since it would tend to increase the conductivity of the path, and consequently the decomposing current, as well as to supply material for conversion into the explosive gases.

In order to give weight to this explanation we must be certain that the moisture does not act simply in such a manner as to increase the conductivity of the discharge path and so, by making a heavier current possible, cause a heavier discharge, more heat, a more intense compression wave, and consequently more intense sound, as explained by the present theory.

For the present at least, this element of uncertainty exists, but we can devise means which in all probability will shed some light on the matter.

But allow it first to be restated that what we desire to prove is:

First, that the sounds accompanying electrical discharges in air are due, at least partly, to the presence of water particles in their paths, and,

Second, that the effectiveness of the water in increasing the sound intensity lies not alone in the increase in the conductivity which it imparts to the discharge path, thus producing a heavier current, more heat, and therefore, a greater expansion of the air, but that *it lies in its electrolytic and thermal decomposition and explosive recombination under the influence of a discharge which is oscillatory in nature.*

Perhaps the simplest proof is to pass a single, unidirectional spark through air heavily charged with moisture, and then to analyze that air for free hydrogen, or simply to pass a second spark for the purpose of igniting whatever oxygen and hydrogen that may have been produced. Should our explanation be correct the second spark will give off considerably more sound than the first, due to the added effect of the oxy-hydrogen explosion.

The production of a single unidirectional spark will now be considered. This problem is not so difficult as it at first may appear. A charged condenser when connected in a circuit of low inductance with a spark gap and a resistance of correct value, can be made to discharge its accumulated energy in one single spark, the damping being so great that insufficient potential remains to cause a second spark. For this condition the resistance must be greater than $2\sqrt{\frac{L}{K}}$, where L is the inductance in henries and K the capacity in farads. Considerable of the stored energy, however, would be lost in the resistance, instead of appearing in the spark itself.

A better but perhaps somewhat more complicated method is to adjust an inductance-capacity-spark-gap circuit to a relatively slow frequency, using a large capacity and as much inductance as is necessary, and then by mechanical means to permit the condenser to discharge at the natural frequency of the circuit during the period of but one half of a complete oscillation, or less.

A diagram will make clear the arrangement of apparatus. This is shown in Fig. 8. A condenser K is connected in a series circuit with an inductance L,

a spark gap *S*, which is enclosed in an inverted glass jar *J* containing moist air, and an auxiliary trigger gap S_1, which can be virtually short circuited for a very brief interval of time by the passage of a bullet *B* fired from a gun *G*. The high potential transformer *T*, fed from an a. c. power line *L-L*, charges the condenser to a potential necessary to break down the two gaps when the bullet passes between the terminals of the auxiliary gap S_1. The length of time during which this passage, and consequently the short circuit, occurs, can be adjusted by sliding the parallel terminal plates of S_1 closer together or farther apart, keeping the actual sparking distance constant.

A brief consideration of the constants necessary in the oscillatory circuit may not be out of place here.

Assume a bullet velocity of 20,000 inches per second, and an adjustment of the trigger gap which will allow a short circuit period of 1/40,000 second; this is equal to 25×10^{-6} seconds, and the length of the gap in the direction of the bullet's motion would be roughly one half inch.

Assume a condenser composed of twenty standard Leyden jars of 0.005 micro-farad each, connected in multiple; the total capacity would be 0.1 micro-farad.

The inductance necessary to produce a natural oscillation period of 50×10^{-6} seconds, or one alternation in 25×10^{-6} seconds, is given by

$$T = 2\pi\sqrt{LK}$$

where *T* is the time of one complete oscillation in seconds, *L* the inductance in henries, and *K* the capacity in farads. These units may also be expressed in micro-seconds, micro-henries, and micro-farads; substituting with these smaller units we have

$$25 = 2\pi\sqrt{0.1L}$$

from which we find $L = 160.5$ micro-henries. An oscillatory circuit with a capacity of 0.1 micro-farad and an inductance of 160.5 micro-henries would therefore be suitable for the purpose at hand.

In the performance of the experiment the spark gaps would so be adjusted that, with the condenser charged to the maximum potential of the transformer, no discharge would occur until the auxiliary gap would be greatly shortened by the passage of the bullet. The gun should be sufficiently far from the spark gap so that there would be no difficulty in determining the apparent intensity of the sound given off by the spark. After one spark has been passed free hydrogen should be found in the inverted glass vessel, and a second spark closely following the first should produce a considerably more intense sound than the first, due to the added effect of the oxy-hydrogen explosion.

The performance of these experiments is contemplated in the near future at Purdue University.

The Movements of the Moon II*

A Popular Survey of Their Marvelous Multiplicity and Variations

By Percy Johnson

Concluded from Scientific American Supplement No. 2125, Page 195, September 23, 1916

This period, however, is subject to slight modification owing to small variations which have not been dealt with, and it was subsequently improved upon in 432 B. C. when the Metonic Cycle was introduced with a much smaller degree of error, while in 330 B. C. Callipus made a further improvement by which all eclipses, and the day on which they would occur, could be predicted for years to come. All these results were solely from observations of eclipses and it was reserved for Hipparchus (190-120 B. C.) to discover the dimensions and nature of the moon's orbit and the revolution of the nodes in 18 2/3 years—remarkable achievements 2,000 years before the invention of the telescope.

The moon's distance, this wonderful astronomer found, by parallax, to be fifty-nine times the radius of the earth—a practically correct result, and he also rightly determined the inclination of the moon's orbit to the Ecliptic to be 5 degrees.

The problem of the moon's distance is more suitable for inclusion in an article dealing especially with the measurement of planetary distances, and will therefore not be dealt with in the present article. Angular measurements on precisely similar principles to those underlying the work of surveyors have revealed that our satellite is situated at a mean distance of 238,840 miles. Such measurements conducted when the moon is in various parts of its orbit show that although viewed from the point of view of its magnitude the orbit is practically circular (as is also shown by the fact that the moon's apparent diameter is subject to no great variation), it is not exactly so. The moon occasionally retreats to a distance of 259,600 miles, while at other times her distance is reduced to 221,000 miles.

Hipparchus, by comparing the intervals between eclipses, discovered that the moon moved faster in some parts of her orbit than in others, and was so led to infer the ellipticity of her path.

Other variations of the moon's motion may be briefly mentioned. The two points at which the moon is least and most removed from the earth (perigee and apogee), by virtue of orbital eccentricity, are found to have a motion opposite in direction to that of the nodes (direct, therefore) which carries them completely round the orbit in 8.8 years. This is caused by the disturbing influence of the sun, which also has another effect, discovered by Tycho Brahe, namely, that of retarding the moon's velocity, so that the sidereal month, which, as has been explained, is the true period of the moon's revolution round the earth, is an hour longer than it would be if the sun could be imagined to be absent.

The earth's path round the sun is also elliptical, however, so the sun's distance is a variable quantity. His retarding influence is therefore variable accordingly, *and although the net result is as stated above*, the moon gets ahead of or falls short of her mean position (i. e. the position she would occupy if the sun had no disturbing effect) according as the sun's distance and influence is lesser or greater, by an amount known as the "annual equation." Now, although all these perturbations were explained by the great and immortal Sir Isaac Newton on gravitational principles, there are others of an exceedingly minute, but none the less definite character, which mathematical science is not yet in a sufficiently advanced condition to account for—and that is saying a good deal. Although in the present article the writer has left the moon's telescopic appearance strictly alone in order to avoid undue length, certain facts must be noted in connection with the movements of our attendant satellite. In the first place, the moon always presents the same hemisphere toward the earth—three sevenths of the moon's surface has never been seen by man, and never will be.

The reason for this is, not that the moon has no axial rotation, but that the period of that rotation is the same as that of her revolution round the earth. In other words, in going round the earth once, the moon turns on its own axis once. Many people experience a difficulty in appreciating this fact, which may be readily understood by the following performance:

Regard some object in the center of a room, such as a table, as the earth, with one's self to represent the moon. Move around the table once, keeping the face always turned toward it. Now, although one has never turned the back toward the table, it is evident that not only has one encircled the same, but that every part of the room has been faced in turn. That is to say, while performing the motion of revolution, a concomitant one of "axial rotation" has also been performed. This is exactly analogous to the case of the moon.

It has been mentioned that only three-sevenths of the moon is visible from the earth, which, of course, means that *more than one half is visible*. It is now to be seen how the extra little bit (one fourteenth) is caught sight of.

It is due to three causes, viz., longitudinal, latitudinal and diurnal libration! In the language of astronomers, how terrifying all that seems. In reality, it is quite simple. Libration in longitude is an apparent swinging of the moon to the east and west and it is brought about owing to the facts that while the moon's rotation on its axis is steady and constant, its movement in space is unequal, as we have seen, sometimes it goes quicker than at others. When it goes quickly, we catch a glimpse round one side, when it goes slowly we get a look just a little tiny way round the other side. Libration in latitude is an apparent swinging of the moon to the north and south. This is brought about by the two circumstances that the moon's orbit is inclined to the ecliptic at an angle of 5 degrees, and that her axis is inclined to her own orbit a further 1½ degrees, the effect being that the moon is now tipped with the North Pole 6½ degrees toward us, and when at the opposite side of her orbit, she has her South Pole tipped 6½ degrees toward us.

Diurnal libration adds to longitudinal libration in that we see farther to the east and west of the moon than we would do without it. It is due to the earth's own daily rotations, which carries an observer to and fro, enabling him to extend his views to the right and left of the moon's face.

It will probably have been noticed by most readers that when, in summer, the nights are practically never dark, and there is no great need for the moon's light, that is the very time she attains her least elevation above the horizon, and therefore sheds the least light; whereas, when the nights are long and dark, she attains her greatest elevation and we receive the best possible benefit from her rays. "Pat" was fairly near the truth, accordingly, when he replied to the question as to whether he preferred the sun or the moon, that the moon met with his preference, as she shone in the night when she was needed, but the sun shone in the day, when anybody could see!

The reason for the moon's varying summer and winter altitudes may be seen if we consider her when "new" and when "full." When "new" she is close to the sun, and in midsummer the moon's greatest elevation is attained when the sun is highest in the heavens, at mid-day. Like the sun, the moon has by far the greater part of her path above the day-time horizon. When the moon gets round to the opposite side of her orbit, and to the "full" phase, it is the remaining and smaller section of her path which is raised above the night-time horizon, and she therefore reaches no great elevation. In winter, the moon, when "new," is again close to the sun, which is this time in its lowest position in the heavens. When the "full moon" is reached she is in the larger section of her orbit and at midnight is high in the sky. In effect, the moon, when full, is always in that part of the sky which will be occupied by the sun in six months' time, and it may have been noted—what never fails to strike the writer—that on a bright moonlight night in winter, the shadows of a landscape produce the impression of a ghostly summer scene at mid-day!

The last subject of remark will be the "harvest moon." In the northern hemisphere of the earth, the "harvest moon" is that full moon which happens nearest to September 23rd, the date of the autumnal equinox.

Its peculiarity is that it rises for several successive nights at practically the same time, and is supposed to be on that account a help to harvesters.

The moon has not ceased to perform its persistent motion from west to east, which has been discussed, by virtue of which it is fifty-one minutes later arriving at the meridian every night. That movement continues the same as before, but its effect in retarding the rising hour of the moon is nullified because at the time of the equinox the path of the moon cuts the horizon at a very oblique angle, so that the movement is almost horizontal and carries it very little farther below the horizon for several nights.

*From *Popular Astronomy*.

Explosions of Boilers Fired With Wood Wastes

According to *The Engineer* explosions have occurred in connection with ordinary Lancashire boilers when hand-fired with wood waste or other bulky material liable to rapid gasification. These explosions are due to the choking of the furnace by a close mass of the fuel, whereby the air is largely excluded from the fire, during the period when combustible gas is being distilled, while a moderate amount of air enters at the back end of the grate, or elsewhere, and becomes mixed with the gas. Such a mixture may accumulate until the fire burns through the fuel and effects an explosive ignition. In such a case the obvious remedy consists in avoiding the choking of the fire, by feeding in smaller quantities at shorter intervals of time.

Volume Changes During the Hardening of Steel*

Conditions That Affect a Troublesome Problem

The problem of the troublesome changes of volume and shape which result from the hardening of steel have received little systematic study, in spite of the practical importance of the subject. It is more or less generally believed that hardened steel expands as a rule, but not equally, along the different dimensions; that sometimes it shortens, and that the composition, particularly the percentage of carbon, the method of quenching, the rate of cooling, and the shape of the piece, influence these changes, which are supposed to be greater in high-carbon than in low-carbon steel, and greater with water-quenching than with oil-quenching. There has been a fair amount of experimenting on quenching and subsequent annealing—notably by Metcalf and Langley, 1880; Thallner (in his treatise on Hardened Steel), Benedicks, Charpy and Grenet, Svendelius, 1897; Maurer (*Metallurgie*, 1909), Leman and Werner, 1911, and special theoretical investigations by Le Chatelier, Tammann, Hanemann, 1912, and others, have touched upon these problems. But the statements made were not concordant, frequently not sufficiently detailed for general interpretation, and they did not offer much advice. The practical man has apparently to put up with the swelling and warping of his hardened pieces. Something like a systematic research was conducted last year at the Charlottenburg Technical High School by Dr.-Eng. E. H. Schulz. His report in No. 164 of the *Mitteilungen über Forschungsarbeiten* does not exhaust his investigation; but he studied the density changes, as to which so much is to be heard in discussion on the hard and soft states of metals, but so little has actually been determined; he finds that the special (alloy) steels are less subject to these volume changes than ordinary steels, and he recommends certain temperatures.

In his investigation, Schulz was guided by the assumption that the cause of the volume changes lies in the differences of the specific volumes of the structural constituents of steels of various compositions when hardened or annealed. He deduced the specific volumes from the specific gravity (hydrostatically determined), and he conducted the first series of experiments so far as possible in such a manner as to deal with samples of uniform structure. That condition restricted him to specimens of rather small size, and the method used gave the most reliable results with disks, about 22 millimeters in diameter, 7 millimeters in thickness, weighing a little more than 20 grammes—smaller than he would have liked. The specimens were ground smooth and weighed suspended by a wire, in air and in water, mostly at 18 deg. Cent.; to substitute alcohol, etc., for water did not prove necessary. The specimens thus treated had been supplied by several works, and varied largely in composition; the carbon ranged up to 1.17 per cent, manganese to 1.25, nickel to 4.5, and chromium to 2.77 per cent. They were heated in a salt bath (potassium and barium chlorides), and quenched in salt baths, oil, or water, and then annealed in steam (up to 100 deg. Cent.), oil (250 deg.), salts (400 deg.), molten lead, or a Heraeus electric furnace; in this last instance the specimen was wrapped with two sheets of asbestos, between which powdered carbon and magnesia were packed. According to Barus and Strouhal, annealing requires a long time when done at a low temperature, and a short time at high temperature; Schulz varied the period from 6 hours to 20 minutes.

It was found that the density of annealed steel decreased as the carbon percentage increased. This decrease was fairly regular, but steels with 0.5 per cent of carbon showed an irregularity which was not noticeable in the quenched condition. The density was decreased by quenching, the more the higher the carbon percentage of the steel. Real good quenching demanded high temperatures; but once a certain temperature (800 deg. or 900 deg. Cent.) was exceeded, the quenching temperature had little further effect on the resulting density. To keep the volume changes small, on the other hand, the quenching temperature should be low; for with rising quenching temperature the volume changes became much more noticeable. In fact, the quenching should, according to Schulz, be effected at a temperature a little above the pearlite-martensite transformation point. In large pieces that treatment would leave pearlite inside the martensite crust, and thus stresses would be set up which subsequent annealing could not quite relieve; yet it would be best for other reasons as well to keep the quenching temperature low. As regards oil and water quenching the volume changes in oil were always less than in water, particularly with eutectoid-carbon steels. But the differences were small, especially with alternating quenching and annealing; concordant results were not easily obtained with oil-quenching, and Schulz does not consider oil-quenching preferable, except for large pieces.

Certain irregularities in the curves suggested a study of metals which have no transformation points, and electrolytic copper and electrolytic iron were selected for this purpose. The quenched copper had a density of 8.909; when annealed at 100 deg., 142 deg., 155 deg., 225 deg., 320 deg., 520 deg., and 700 deg. Cent. (we do not give all the figures), the density was 8.911, 8.919, 8.921, 8.913, 8.909, and 8.902. The changes were hence small, but there was a distinct contraction when the copper was annealed near 150 deg. Cent. The initial density of the electrolytic iron was 7.892; annealed at 1100 deg. the density was 7.899; quenched at 1100 deg., 7.889. The quenching hence produced a very slight loosening of the iron, which was hardly influenced by various thermal treatments of this iron. Small samples of the electrolytic iron (large samples were not available) were then fused in a clay crucible, and quenched either at 1100 deg. or at 850 deg. Cent. Again, there were only very slight fluctuations in the density, but the annealing at various temperatures brought out peculiar features. Between 100 deg. and 250 deg. the density had a decided maximum of 7.905, which was followed by a minimum of 7.870, and ball hardness tests also displayed a maximum hardness at about 150 deg. Cent. This peculiarity at about 150 deg. had been noticed by Maurer, but only in high-carbon steels, and it is striking that it should appear in copper as well. The density changes in the case of the steel specimens tested ranged up to about 0.1, we should have mentioned.

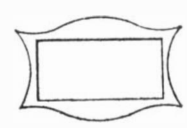
We have partly anticipated the tests made on annealing after quenching. In these tests the annealing temperature was raised in steps from 70 deg. up to 880 deg. Cent., and it was shown that annealing diminished the volume of quenched steel the more as the carbon percentage rose. But the volume change did not proceed at a regular rate, and phases had to be distinguished. Up to 150 deg. (always Centigrade) the volume decreased; then the volume increased up to about 200 deg. (eutectoid steels), or above that (for supereutectoid steels); this phase was most marked in high-carbon steels. When annealing was continued above that temperature of about 200 deg., the volume decidedly decreased again and attained its minimum (i. e., the density was maximum) at 430 deg. for all the steels. Annealing at still higher temperatures had very little effect, rather tending to produce an increase in volume; the original density of the quenched steel was not quite recovered by high-temperature annealing, however. Thus all the carbon steels finally behaved similarly in principle. This statement contradicts Maurer and others, and that the rate of cooling after annealing (in the furnace, in air, in water) was found of no importance is not in accordance with some other observations either.

These tests were extended to special steels. In these the volume changes on quenching were less marked; but the percentages of other metals in the specimens (mentioned above) were not high, and this promising part of the research requires further study. Nickel-steel followed carbon steels; chromium (specific gravity 6.8) tended to lower the density; manganese, although itself of higher density, 8.0, likewise, to a lesser extent; chrome-nickel steels gave greater volume changes, however.

Other experiments concerned the assumed shortening of hardened specimens. These tests were limited to wires, 5 millimeters in diameter, of the various carbon steels. There was never any shortening, but always lengthening, increasing with increasing carbon percentage, and fairly proportional to the length of the specimens.

Discussing the experiments, and especially also the phases referred to, Schulz finds that his results are in agreement with the observations of Heyn and Bauer on the solubility of steel in acids and other properties at different temperatures (which they ascribe to osmondite), but do not fit into the allotropic modification theory. Schulz favors Hanemann's views. On quenching, martensite needles are formed in the austenite, which is first compressed by them; but the decomposition of martensite begins at 100 deg., and above 150 deg. austenite becomes able to take up the compression stress, and is itself decomposed in the range 250 to 450 deg., in which the martensite decomposition is completed. On the other hand, rising temperature expands both martensite and austenite, and as the expansion predominates in the interior, and is still in the annealed state, while contraction goes on in the cooled surface layers, hardness cracks are developed.

These conclusions are supported by the further experiments on the volume changes in larger samples, which were all made with a carbon steel of 1.01 per cent of carbon, however. Bars and rods were cut to length and turned, heated in salt baths up to 900 deg., and quenched in water. Cylinders up to 50 millimeters in diameter and 60 millimeters in height were particularly studied, by micrographical and other methods. It was found soon that, for reasons presently to be explained, thin plates and cylinders of dimensions of less than 10 millimeters had to be considered apart from bigger specimens. In cylinders and bars, again, squat (low) and high specimens had to be distinguished in a certain sense. Squat cylinders swelled in the manner indicated in the diagram (below), which represents an axial cross-section before and after quenching; the peculiar swelling was less striking in cylinders of



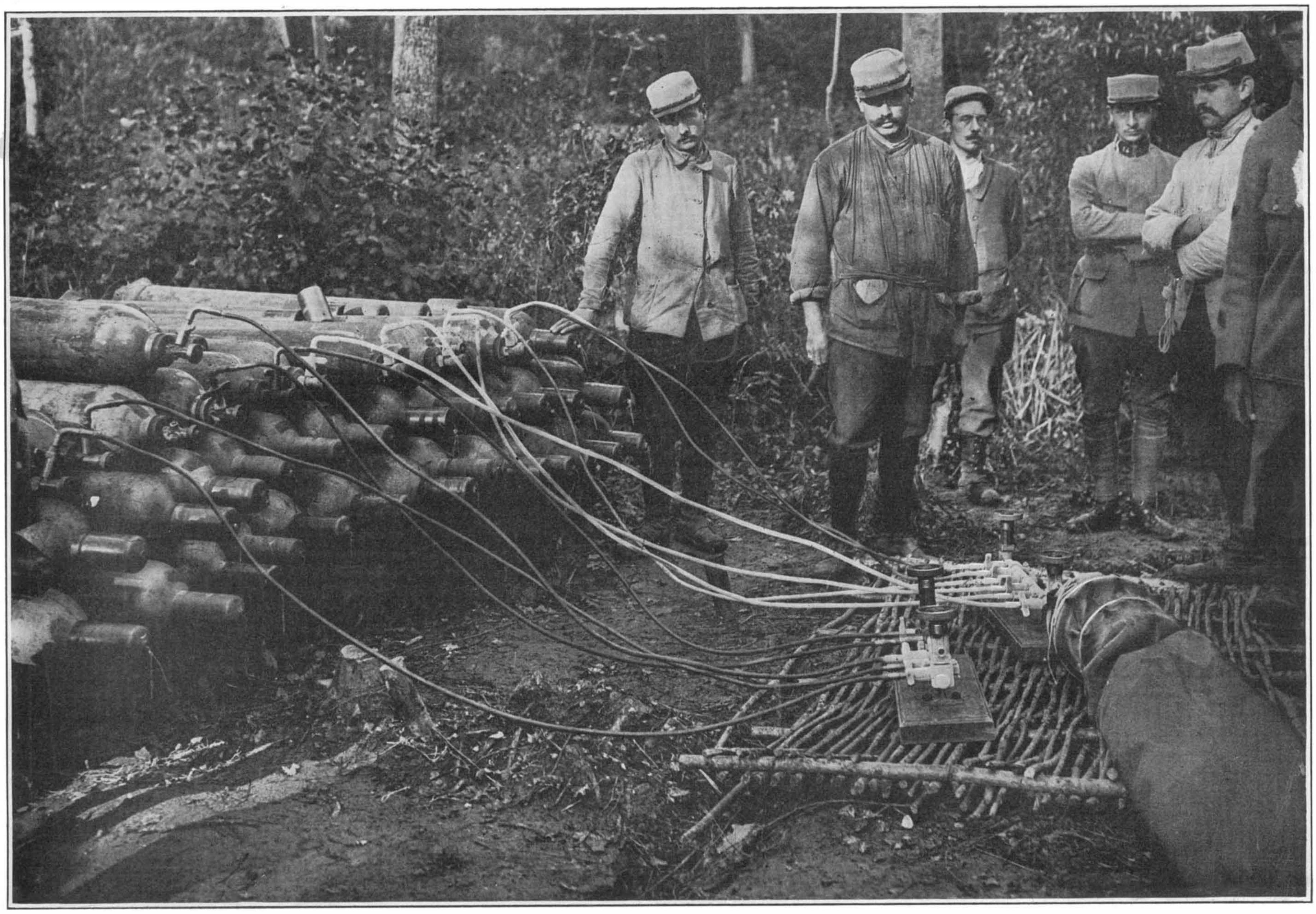
greater height than diameter, which cylinders increased more uniformly in length, but bulged in diameter about the middle of the rod. To investigate the changes going on in the interior, thermo-couples were inserted in holes drilled parallel to the axis. We cannot enter into the details of the explanation which Schulz suggests for the shapes assumed. But he concludes that a crust of martensite is formed about the core, which remains in the annealed state. This crust had always a thickness of about 5 millimeters, and hence pieces of dimensions not exceeding 10 millimeters would be martensitic throughout, without any osmonditic core, and would expand more uniformly than thicker specimens.

In his final explanatory remarks concerning the causes of hardening, Schulz properly accentuates stresses. They are of two kinds, the first purely physical or thermal, the second due to the different natures and volumes of the different constituents and their textures. To relieve the stresses entirely by annealing will only be possible, he thinks, in cases of small specimens, not in specimens of larger and unequal dimensions, because the complex groups of factors interact in various ways. But something can be achieved by hardening at definite temperatures, which should be low in general, by avoiding eutectoid steels, which particularly incline to cracking, and by substituting special (nickel) steels for them; that is to say, by replacing some of the carbon by nickel or other metals. That eutectoid steels should be most liable to develop hardness cracks, Schulz ascribes to the circumstance that in them all the transformations take place at one temperature (about 700 deg.), and not in several stages.

*Engineering.

Destruction of Short-Tailed Petrel

Dead bodies of the short-tailed petrel, to the number of many hundreds, have periodically been found along the beach at Ulladulla, New South Wales, and a like mortality prevails on some islands a few miles off the mainland. Naturally such discoveries have given rise to much speculation among ornithologists. As a rule it is attributed to disease, starvation, or storms. But Mr. G. Basset Hull, in the *Emu* for April, advances what seems to be a much more probable explanation—to wit, that these are the victims of the struggle for breeding territory with the larger and more powerful wedge-tailed petrel. Support is lent to this view from the fact that on one island, where the wedge-tailed species were breeding in large numbers, no burrows were found tenanted by the short-tailed species, but their dead bodies were found outside the burrows of their larger rivals. If, indeed, the smaller species is harried, buffeted, and finally driven off in an exhausted state by the larger, then the struggle for existence in the case of the short-tailed petrel must be indeed severe. It is to be hoped that an attempt will be made to set this matter at rest, for it raises a point of quite exceptional interest.—*Nature.*



Filling a kite observation balloon with hydrogen gas.

The compressed gas is contained in the steel bottles at the left, which are connected by metal pipes with the controlling valves seen in the foreground. From these valves the gas is admitted to the large canvas tube, seen in the right hand corner of the picture, which conducts it to the big gas bag, with which it is connected.

Aeronautics in the Great War*

The Captive Balloon, and the Important Work It Performs

It would indeed be premature to attempt at this time to write the history of aeronautics during the two years of warfare which have passed. Both in its rôle and in its technique aerial science is far more complex than would be imagined. With its means of transportation, its flying workshops, its meteorological posts and wireless depots, its photographic apparatus and the astonishing results attained therewith in discovering the dispositions of the enemy, and its many other possibilities that the general public can only suspect. Its organization will later be the subject of curious revelations well calculated, to inspire a legitimate admiration for the great breadth of achievement.

The great Zeppelin raids are mentioned often enough; but there are other dirigibles, of which we do not hear, which travel about freely through the air on business less spectacular, but perhaps more useful. And there are still other air machines on the subject of which silence is almost complete.

It has been an exceptional circumstance for anyone to perceive that aeroplanes and dirigibles do not alone constitute the entire aerial equipment of an army. At the beginning of May, 1916, a report announced that a score of captive balloons—sausages, as they are called in the language of the trenches—had burst their moorings during a hurricane and, careaning away through the air, had been carried for the most part within the lines of the enemy, but that a number of observers had been able to descend in parachutes, while still above our positions, and thus avoid capture.

Have we, then, captive balloons? And are these equipped with parachutes? These are things which many people appreciated for the first time on reading of this incident.

All these diverse machines are evidently planned for different rôles. Events already make it permissible to reveal the tactical rules governing their use. As to their utility, in spite of the uncertainty and experiment necessarily attendant upon their novelty, the services rendered have been so great that it is no longer possible to conceive of an army not equipped with the aerial arm; such loss would make defeat the certain result of an encounter with a properly equipped force.

Looking at the matter strictly from the standpoint of reconnaissance, the considerably increased effectiveness of fire to-day makes this service by the cavalry extremely difficult, and the information they are able to procure insufficient. It has indeed been possible on the Russian front to drive the old fashioned audacious cavalry raid right through to the hostile rear; but such operations have been quite out of the question upon the long continuous line where the adversaries are deadlocked upon the western front.

It is not enough, however, to know what goes on along the fringe of the hostile front with which we are in direct contact. The facilities of transportation which make possible the use of railroads for rapid concentration and shifting of forces along interior lines makes imperative a continuous surveillance of the enemy's reserves and all movements thereof; various types of aircraft are the only means of foreseeing and forestalling his projects.

The singularly augmented range of cannon permits the setting up of these far from the advanced line, and affords the best means in the world for their concealment. How are these positions to be marked in the absence of elevated observatories, of aerial observatories? But of what inestimable value, on the other hand, are the reports of an observer who can move about in the air, who does not content himself with mere looking, but who brings back an accurate photographic plan of the hostile trenches, of their points of resistance, of the positions of batteries and of mitrailleuse!

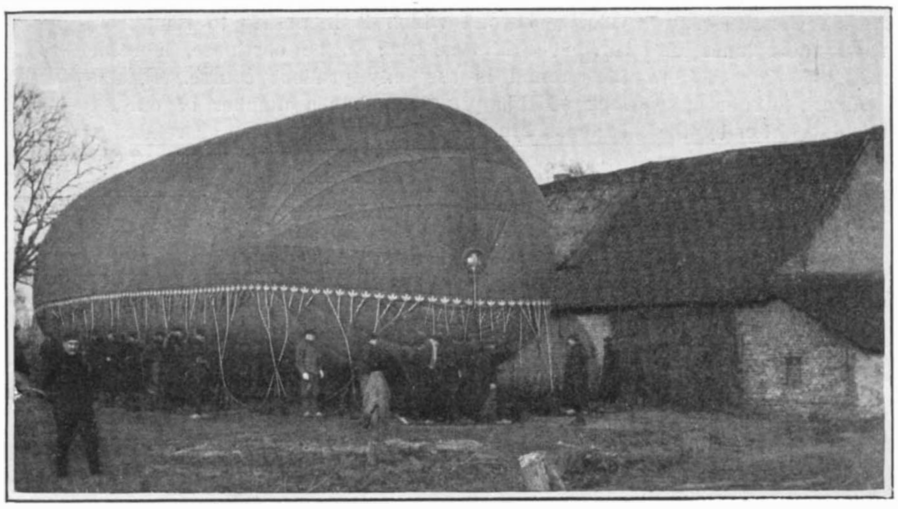
For the pursuit of this sort of reconnaisance an elevated position is essential in order to direct the artillery fire; and we can at length get a glimpse of the services to be expected from an aerial navy which can penetrate to the very heart of the adversary's lines, destroying, by an effective bombardment, his works, his communications, his munition depots, his food supplies, and his very reserve forces themselves.

Such are the three ends—reconnaisance, direction of fire, and bombardment—to which the aerial service is put in present day warfare, filling a great void in the resources available to the army. To meet these demands satisfactorily, it will be clear that various types of aircraft should be employed, each appropriate to its own particular rôle. This is why it is incorrect to assume that aeroplanes suffice for all purposes, to proscribe captive balloons and dirigibles as superfluous. Differing in their nature and their special properties, each of these has its special use, as we shall see.

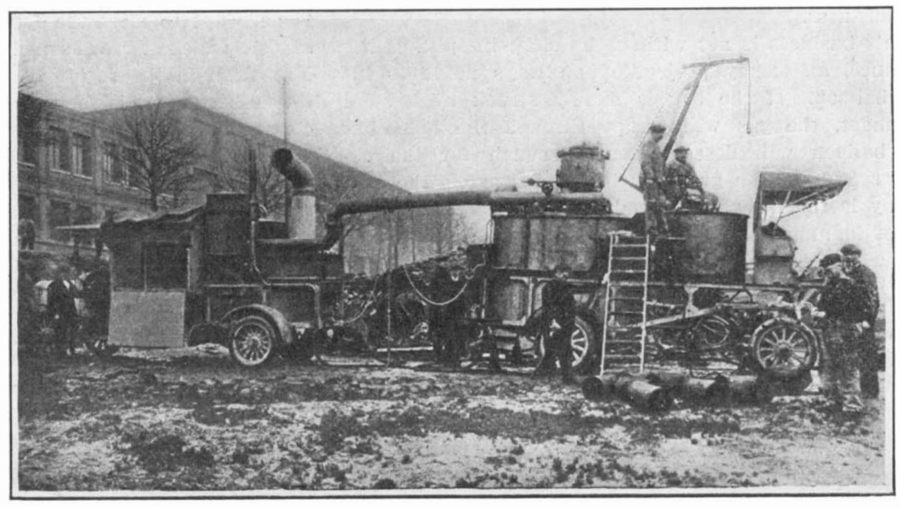
It is only within the past few years that, in military circles, any account at all has been taken of the great rôle to be played by aviation. This scepticism is easily enough explained by the imperfect state of aerial technique at the start, and above all by the insecurity of the heavier-than-air machines. Progress has followed the beacon of experiment. So we need not be greatly surprised to find that, although the first steps in military aviation were taken by the French army, the war caught the aeronautical service of France in a period of uncertainty and in a rather unorganized condition.

If the aeroplane seems to have enjoyed an enormous preponderance in this conflict, we know that from its first invention the balloon has been regarded as a valu-

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *la Nature*.



Preparing a captive observation balloon for an ascent in Belgium.



From the Illustrated War News

A French portable hydrogen generator for inflating airships and observation balloons.

able military auxiliary; and if it has played a less prominent rôle in the present war, it is none the less true that it has found free use in the form of captive or dirigible. It is, at least, no fault of the Germans that large capacity dirigibles have not been of decisive importance in certain operations. Captive balloons and dirigibles, as well as aeroplanes, form part of the equipment of both sides.

Enough has been written of aeroplanes; we wish to look now into the domain of the lighter-than-air craft.

Before the war which brought into conflict the most formidable and most scientifically organized armies ever seen, it would have been possible to believe that the captive balloon was altogether obsolete and incapable of rendering any appreciable service. It seemed that the great range and accuracy of modern artillery would confine its use to such distances from the enemy that observations so made would be of no utility. The most that was hoped for it was employment in the surveillance of the approaches to a fortified place during the preliminaries, at least, of investment.

But experience has shown that in the present phase of the war, so closely resembling actual siege operations, the captive balloon is still available, without too great risk, for certain services in the performance of which it could not be replaced. For this comparatively motionless point of observation presents the same advantages over the ever-moving aeroplane that a fixed post sentinel has in comparison with a patrol. The observer in the basket of a captive balloon has continuously before his eye the entire terrain. With a good telescope properly installed, and a map, he is entirely at his ease, and he need lose no detail of what happens within the vast field of his horizon. By means of his telephone-wire he is in constant communication with the ground. Even if distances are such as to afford him only a remote and very general view of his objective, his indications will be sufficient to dictate the opportune moment for the launching, if need be, of several aeroplanes charged with the making of a detailed reconnaisance.

It is also to be recognized that the captive balloon is of value in directing the fire of the artillery, which nowadays is seldom able to see the object of its bombardment.

Without going back to the "aerostiers" of the First Republic—those of Maubeuge and Fleurns—we recall that Col. Charles Renard designed for the French army, after the War of 1879, a complete outfit, worked out with great care, and light enough to follow all the movements of field artillery. A spherical balloon of pongee silk, 540 cubic meters in capacity, sustained an osier basket by means of an ingenious suspension device which afforded the observer facility for maintaining his balance and his orientation. A steel cable 1,000 meters long connected the balloon with a windlass, itself carried upon a horse-cart or an automobile. Another vehicle carried the tubes containing the compressed hydrogen for replacing the daily loss of the balloon. Conveyances for the rigging, and repair wagons completed the train and made it self-contained.

The spherical form is most desirable, in the sense that it encloses the greatest volume of gas within the least surface, and therefore weighs least. But a spherical balloon offers feeble resistance to high winds, which beat it toward the ground so violently that temporary suspension of observations is too often necessary. So it appears that to resist the action of the wind, and to avoid oscillations of sufficient magnitude to hamper observation, it would be preferable to substitute, for spherical type, an elongated balloon, equipped like a kite for self-orientation in the wind. A kite-balloon, in fact, receives from the wind a vertical thrust which so strongly re-inforces the proper ascensional force that the balloon tends to take a position directly above the point of anchorage; and the stronger the wind, the stronger this tendency.

So, while the spherical balloon is admirable for calm weather, it is impracticable under the most moderate winds. In such circumstances the kite-balloon is called for. Its rigid orientation facilitates observation, and it is much easier to hide it from view in bringing it back to earth, since it is of less height than the spherical type.

These advantages are sufficient to compensate for its increased weight; so the elongated captive balloon has been very generally adopted. It may be said that a certain number of spherical captive balloons are still in use at the front, undoubtedly because they were on hand before the war. While, during the theoretic development of the problem, we have clung to our spherical type because of its simplicity and economy, the Germans have preceded us by many years in the construction of kite-balloons; but to-day, at any rate, the two adversaries are approximately on the same ground.

The windlass truck is concealed under sheaves of grain, and only the cable that holds the balloon is visible.

The German balloon—the "dragon" balloon—invented about 1897, is attributed to the collaboration of Major von Parseval and Capt. von Sigsfeld.

The body of the cylindrical balloon is terminated by two spherical caps. To obtain a capacity of about 600 cubic meters, it is given a length of 13.5 meters and a diameter of 6 meters—an elongation of 2.25 diameters.

By means of intermeshed cords fastened in the region forward of the keel to the ropes which extend along the envelope, the balloon is attached to its retaining cable, which is wound about a windlass carried on a special truck. These cords are so arranged that the balloon, under the weight of car and passengers, takes naturally an inclination of twenty degrees; but since the inclination of the cable itself varies with the velocity of the wind, it is necessary, in order to hold the balloon in its normal position, that the junction of the cable with the system of cords be highly flexible. To this end the cable terminates in a pulley which rides in a suspended cradle. The basket, in its turn, is suspended a bit aft by the same cords.

In order to insure a good anchor-hold and fixity of orientation while in the air, it is necessary that the force of the wind shall always play upon a regular, symmetric body. This requires that the shape of the body shall be permanent and independent of the amount of gas contained. To attain this the exterior envelope incloses an auxiliary air-ballonnet occupying, when filled, a quarter of the total volume. This ballonnet is formed by a cloth partition which cuts off a compartment at the stern, the seam joining this partition to the main envelope being horizontal when the balloon is at its normal inclination of twenty degrees.

In addition to the ballonnet, we must here mention that, just as every kite carries a tail attached to its stern to direct and steady it in the wind, so every dragon balloon is furnished with a caudal attachment or governor. This consists of a pocket of air, shaped like a segment of a torus, surrounding the cap at the stern and prolonged a trifle under the body, and attached to the main envelope by a special system of meshed cords.

In a dirigible the inflation of the ballonnet is effected by means of ventilators which drive in the air. But the fixity of the kite-balloon in the wind allows the automatic inflation of its ballonnet and pneumatic governor through flexible air pipes, opening from a tunnel toward the bow, into which the air flows naturally. And this, of course, necessitates a safety valve to prevent the pressure in the ballonnet from exceeding a certain safe limit, no matter with what force the wind may blow into the feed-tunnel.

The trim of the body is completed, and the stability of orientation increased, by two ailerons of flexible cloth attached at either side of the balloon, and which rise under pressure of the wind by stretching the light cords fastening them to the envelope. Finally, at the extreme stern, there is a long tail entirely like that of the ordinary kite—a plain rope carrying a series of inverted cones of cloth, into which the wind blows.

The German army has in service eight types of mounted dragon balloons, varying in capacity from 550 to 1,140 cubic meters, the larger ones carrying two observers. In addition there are seven types of the same series, but much smaller, in which the basket is replaced by a sack of ballast of five or ten kilograms weight. These serve either for meteorological observations or to carry the antanae for wireless outfits, and vary in capacity from 10 to 108 cubic meters, according to their purpose.

The inflation of a balloon, so laborious when undertaken with poor management of gas under low pressure, is in the field the simplest operation in the world. The inert and lifeless envelope—the "skin" of the balloon—is laid out at full lengths in folds upon the ground. Steel tubes are on hand containing hydrogen at a pressure of a hundred and fifty atmospheres. Light pipes are rapidly attached to the valves of these, and the hydrogen passes into a varnished cloth sleeve connected with the inflation valve of the envelope.

The big bag rises and swells out. Soon the balloon is free from the ground, to which, however, it is still secured by sacks of ballast hooked upon the ends of the control ropes. The monster is far from handsome; it is but partially inflated, and all wrinkled; its languid tail droops sadly. The wicker basket is arranged in place; the observer climbs in and arranges his apparatus; the steel cable is placed upon the windlass of an auto-truck. An order "cast off;" the balloon rises; the gas expands little by little; at length the envelope is wholly dilated. The wind begins to enter the pocket of the governor, which in its turn swells out, and under the rays of the sun the enormous aerial animal seems to take on life.

The observer assures himself that he has his map and his glasses under his fingers; he fastens the straps of his parachute under his armpits and about his thighs;

he adjusts his telephone headpiece; and he is ready for business.

This business is not without its risk; in spite of the distance, an enemy projectile is always liable to hit the balloon. If the bag is merely struck by a solid fragment, the gas will escape through the hole, but the balloon will descend gently enough for the observer to gain the ground without damage. The real enemy is the incendiary bomb dropped upon this bubble of inflammable gas from an aeroplane flying above. The wisest course, when the approach of this dangerous foe is signalled, is to bring the balloon at once to earth and conceal it as well as possible; otherwise it is very apt to meet the fate of the six German "sausages" which were burned from our aeroplanes on May 22nd in the region of Verdun.

Another enemy is the hurricane. As a kite is brought closer and closer to a directly vertical position by the force of the wind, the tension upon the line increases rapidly. So it is with the captive balloon. The steel cable has great strength; but its point of rupture cannot be made indefinitely high without increasing its weight beyond all reason. The heaviest cable that can be used to advantage in this work weighs 14 kilograms per 100 meters. There is therefore a wind velocity beyond which it is unsafe to remain in the air. It avails nothing to be obstinate, a return to the ground is the only prudent course. It was for lack of this prudence that a number of our captive balloons broke their cables last May, as related above.

So the captive balloon plays in the present war, a rôle less spectacular, to be sure, than that of the dirigible or of the aeroplane, where everything is left to the initiative and the temerity of the pilot; but it is a rôle none the less useful and none the less deserving of our attention.

The Indian Jute Industry*

Its History, Cultivation and Manufacture

By C. C. McLeod, President of the London Jute Association

The early history of jute lies in obscurity. It may have been cultivated in a small or large way centuries ago, and, personally, I have no doubt it was—for the reason that the natives of India are so conservative in their ways that what we may have thought was a beginning in the eighteenth century may have been as ancient as some of the temple ruins one sees or reads about in various parts of India. As a pot-herb the leaves are extensively used in India still, and I have the authority of the "Encyclopædia Britannica" for stating that jute leaves were used for this purpose from very ancient times, if the plant may be identified with the "mallows" mentioned in Job xxx 4, "Who cut up mallows by the bushes." The same authority states: "It is certain the Greeks used this plant as a pot-herb, and by many other nations around the shores of the Mediterranean this use of it was and is still common." It might even suggest that tents used in ancient times by the great army of Mahomet were probably partly made of the fiber. I must not, however, labor this point, and if I start on the fact that we have some knowledge of jute being handled in a small way in 1746, and grown pretty freely in the northern districts of Bengal in 1804, we have at least an authentic starting-point. Mr. Finlow states that in 1829 some twenty tons of jute were exported from Calcutta, and although the next five years only saw a small advance, averaging under 600 tons per annum, the exports increased very considerably during the next ten or fifteen years, and eventually reached the very substantial figure of 80,000 tons in 1911-12.

The usual custom is to estimate the out-turn for the season at 15 maunds per acre or 3 bales of 400 pounds per bale, and on the whole the system has come out with a moderate degree of accuracy. Apart from this, climatic conditions play a prominent part. You may have a large area sown without obtaining a large crop if the monsoon is fitful or deficient, and *per contra* a moderate area under favorable climatic conditions can yield a crop that exceeds all expectations and calculations.

There are two principal species of jute, *Corchorus capsularis* and *Corchorus olitorius*. The former is easily distinguished by its round pods, while the latter has long cylindrical pods. *Capsularis* is almost exclusively grown in the northern districts, while *Olitorius* is extensively cultivated in the Hooghly and twenty-four Pargana districts and in Western Bengal. This latter species has the advantage of being more easily decorticated than *Capsularis*, which is of considerable advantage. On the other hand, *Capsularis* plants can stand submersion better than *Olitorius*, and, generally speaking, are less easily affected by adverse climatic conditions. Notwithstanding these peculiarities, it has been proved beyond all doubt that each of these principal species of jute would yield a different class of fiber if subjected to different conditions of soil and climatic influences. I will not go deeper into the question of strength and color, for this is also so dependent on circumstances that reliable data are not obtainable. I may, however, usefully add that the best jute is produced on the higher lands, especially if well cultivated. Jute on the lower lands is generally cut before it has time to ripen or reach maturity, owing to fear of floods and loss of plant. Another species of jute is grown chiefly on the Madras side, called *Hibiscus cannabinus*, known on this side as "Bimli" jute. It is in every respect inferior to the Bengal jute, being shorter and coarser. It has, however, come into considerable requisition in late years, owing to an improvement in the treatment and packing, and also, I believe, on account of its comparative cheapness as compared with Bengal jute. Its production has also considerably expanded during the last five or six years.

The preservation of seed has received considerable attention of late years, helped by experiments conducted by the Government Department of Agriculture. In former years seed was raised from stunted plants on the outside edges of the jute fields, and naturally, being obtained from the poorest plants, proved disappointing. As in dealing with many other industries in India, the ryot pays insufficient attention to keeping seed grown from the healthiest plants, with the result that, year after year, the same old seed from the same old and weak plants has been preserved since the original bagful came out of the Ark! A little more care and an interchange of seed would materially increase the out-turn and improve the quality of the jute as well.

It would take a much longer time than I have to-day to deal at length with the intricate question of soil and its treatment, and I will merely state that jute in India can be grown in almost any soil which has a good depth and has the necessary material required to fertilize it. On the alluvial soils in Eastern Bengal, where the rivers and khals leave a rich deposit annually, jute grows freely without any artificial help. On the other hand, the higher lands are heavily manured and yield heavy crops, not only on this account, but also owing to the fact that jute grown on the higher lands is immune from floods and has a much better chance of ripening. An ample rainfall is, of course, an essential to supply moisture, and later on steeping water for "retting" the plant when cut. Rainwater is generally considered more beneficial than irrigation, however ample.

To take you through the various stages of ploughing, sowing, harrowing and weeding, would occupy far more time than I have at my disposal, and I must shorten the description as much as possible. Early in February the ploughing commences on the low-lying lands and continues to the beginning of May on the higher lands.

The process is crude enough, and it is difficult to believe that at a later stage, when the plants appear in full growth, a scraping of the earth with a crooked piece of stick drawn by a pair of emaciated bullocks could possibly have produced such a result. After the land is ploughed and pulverized the seed is sown broadcast and in quantities of from six pounds to twelve pounds an acre. After this has been done the ground is raked or harrowed and the plants allowed to germinate and grow to a height of a few inches, when the rake is again used to stir up the soil and stimulate the growth of the plant. This raking process is also useful in keeping down the very healthy crop of young weeds that come up with the germinated plant. At times they grow quicker than the plants, and are very troublesome. At a later stage weeding and thinning take place, and then the plants are allowed to reach maturity without further interference.

The period for reaping varies according to circumstances and climatic conditions. On the lowlands cutting starts about the end of June; if there is any danger of the fields being flooded, cutting is commenced even earlier. Early-cut jute is never very satisfactory; it is usually immature, short and mossy. The process of "retting" (soaking in water) usually takes anything from ten to thirty-five days, according to the time of year. In July and August, when the temperature of the water is high, the process is quicker and the jute is ready for further handling, but in September and later months it takes quite a month to "ret" the plants. The experienced grower can tell at once when the "retting" process is complete, and then the plants are taken out of the water, the fiber extracted, washed and dried—and here again climatic conditions play a prominent part. Heavy and continuous rain prevents the drying, and very often, as we know, makes the crop late in coming to market. When the jute is sufficiently dry, it is rolled up in drums and sent to the nearest market or sold locally to small dealers, who take it away to some of the large centers in country boats and dispose of it at a considerable profit. Many of these country boats make their way down to Calcutta and sell their cargoes to the jute mills along the River Hooghly.

The principal jute markets are Naraingunge, Serajgunge, Chandpur, Madaripur, Jagannathgunge, Purnea, Julpaiguri, Koostea and Goalundo, and during the season these centers present scenes of animation and extraordinary activity.

At these great centers you will find not only native merchants purchasing jute, but also firms managed by Europeans buying for Calcutta mills, and calcutta merchants buying suitable qualities for baling in Calcutta for export. A very considerable quantity of jute purchased at these up-country markets is resold to balers in Calcutta.

In the earlier days of the industry the jute came down packed in drums by country boats and river steamers, but in later years the railway has carried by far the most of it.

The use of jute-presses in the jute districts has greatly facilitated transport. These presses are used to pack what are known as "Cutcha" bales, containing three to three and a half maunds, and are usually sold to mills and large balers. The exported bale to Europe and other countries is of a fixed standard of five maunds, or four hundred pounds. The packing is chiefly done in Calcutta. Adjoining the press-house are large stores or "go-downs," where jute is assorted into the various standards required for the European market. The packing business was formerly in the hands of Bengalis, but with two exceptions this part of the trade has passed into the hands of Marwarris, outside of course, of the European balers.

Before leaving this part of my subject, I may just say a few words on the cost of production and the prospects of increasing the area. Mr. Chaudhuri, in his book on "Jute in Bengal," written in 1907, puts the cost of production at Rs. ⅝ per maund, but I fancy this is far below the cost of the present day, for, as with all other products, enhanced prices generally lead to an increased cost of production. It is rather difficult to account for it except in this way. Formerly, when the area was smaller, the ryot could conveniently manage to cultivate and harvest his little plots with his own family, without incurring extra expenditure for outside labor; but with the increased demand and higher prices ruling, larger areas have been cultivated, necessitating the use of hired labor, which has materially added to the cost. This leads me to deal with the prospects of increasing the area.

It is, of course, quite a simple matter to point to the vast expanse of country available for jute cultivation, looking to the fact that jute only covers an acreage of 3,000,000 acres out of some 60,000,000 acres in cultivation in the province of Bengal and Assam. There is no lack of suitable land, especially in Assam, but the labor question absolutely prohibits expansion. It has been attempted at various periods by European firms, who have experimented with labor-saving implements; but, so far as I am aware, none of these has proved

*Journal of the Royal Society of Arts.

successful, and we must fall back on our old friend, the ryot. That the existing area could be made to produce a very much larger crop has been proved beyond doubt. A more scientific system of cultivation and greater care in the selection of seed and the application of fertilizers on higher lands would probably double the out-turn per acre in a normal year.

Climatic conditions will always remain an important factor in determining the annual out-turn on any given area. I therefore venture to state that while another million acres could be added to the existing area, so far as suitablility of land is concerned, the question of labor will bar it; and we can only rely on improved agricultural methods to increase the crop. It has been stated by experts in jute that the crop has seriously deteriorated during the last ten years. The statement is confirmed by many spinners with whom I have discussed the subject. I do not think it is at all difficult to account for it. It is, I think, due to the fact that the enhanced value of the article has induced the ryot to cultivate more jute than he can handle, and that the large crop now being produced is beyond the limit of those who are engaged in it. I do not think the plant has deteriorated at all, but rather that the rush to grow it with insufficient labor has gradually, in late years, led to carelessness in the harvesting and curing of it, consequent on the desire to get it on to the market and secure the higher prices now ruling. I think this has also something to do with the excessive moisture found in the fiber in late years. The same time and trouble are not expended in drying it properly, and while the ryots who grow the jute may and do, as a rule, deliver it dry to the middlemen, the latter, especially the smaller dealers, are known to water it freely in order to increase the weight. This has been proved beyond doubt, and evidence was obtained some years ago that quite 75 per cent of the jute reaching the Serajgunge markets was freely watered and sanded. It is difficult, indeed, almost impossible, to put an end to this practice as the jute passes through so many hands, and I very much doubt if legislation, urged and even contemplated a few years ago, would have put a stop to it. Wet-packed jute quickly deteriorates in color and strength of fiber, and it is not unusual to find bales of jute reaching this country with heart damage varying from 2 to 30 per cent, or even more.

Normally, jute is the cheapest fiber for providing bags to carry the produce of nearly the whole world. It carries all the valuable wool and grain from our Australasian colonies, from America, South America, and, indeed, any quarter of the world where grain and oil-seeds are produced. It is used for the internal carriage of goods in every part of the globe, for covering cotton bales, tarpaulins, carpets, and even shirts are made from it in Dundee. Hem Chundra Kar, in his official report on jute issued many years ago, gives the following interesting varieties of uses to which jute was put in the Midnapur district: (1) Gunny bags; (2) string, rope and cord; (3) *kampa*, a net-like bag for carrying wood or hay on bullocks; (4) *chat*, a strip of stuff for tying bales of cotton or cloth; (5) *shika*, a kind of hanging shelf for little earthen pots; (6) *dulina*, a floor cloth; (7) *beera*, a small circular stand for wooden plates, used particularly in the poojahs; (8) brushes for painting and whitewashing; (9) *ghunsi*, a waist-band worn next to the skin; (10) *gochh-dari*, a hair-band worn by women; (11) *mukbar*, a net-bag used as a muzzle for cattle; (12) *parchula*, false hair worn by players; (13) *rakhi-bandhan*, a slender arm-band worn at the Rakhi-poornima festival; (14) *dhup*, small incense sticks used at poojahs; (15) *dola*, a swing on which infants are rocked to sleep. It has, as you know, been extensively used for sandbags in the present war. It has no real rival, and is not likely to have as far as we can see.

In the early eighties experiments were made in jute culture in Egypt, and in the Dundee Trade Report of March 23rd, 1881, the following statement appears: "Some samples of jute grown in Egypt are being shown here. Reports on quality are varied, but, considering it is a first attempt, on the whole satisfactory. It proves beyond doubt that Egypt is capable of producing this material, and for the trade of this district this is a matter of great importance, as having the fiber grown near at hand will enable our manufacturers to compete more successfully in all markets with the Indian mills." But the project does not appear to have gone much further, no doubt on account of the cost of labor making the cost of production impossible.

A few years back *Textilose* made from paper was exploited as a substitute, but it has turned out unsuitable owing chiefly to the fact that it cannot stand immersion in water without falling to pieces. The Germans have lately exploited a fibrous plant (*Epilobium hirsutum*), which they assert will oust jute from the German markets. I very much doubt this. Even if it had the spinning qualities of jute they would find the cost of production so prohibitive that it could never compete with a fiber grown under the same conditions as jute.

The manufacturing trade in jute has, like the raw material, an obscure early history, but has made up for it by coming very rapidly to the front and assuming an important position in various parts of the world. In relating the progress of jute-spinning and weaving by machinery we have ample data to go upon, and while we are unable to trace back the earlier history of hand-loom spinning in Bengal, we have records of its existence in the earliest days of our entry into that country. In this connection I cannot open the history of jute-spinning and weaving more appropriately than by giving you a paragraph from Dr. Forbes Royle's "Fibrous Plants of India," published in 1855, in which he quotes a letter from a Calcutta merchant as follows: "The great trade and principal employment of jute is for the manufacture of gunny *chuts* or *chuttees*, i. e., lengths suitable for making bags. This industry forms the grand domestic manufacture of all the populous eastern districts of Lower Bengal. It pervades all classes and penetrates into every household; men, women, and children find occupation therein. Boatmen in their spare moments, husbandmen, palankeen carriers, and domestic servants; everybody, in fact, being Hindus—for Mussulmans spin cotton only—pass their leisure moments, distaff in hand, spinning gunny twist. Its preparation, together with the weaving into lengths, forms the never-failing resources of the most humble, patient, and despised of created beings—the Hindu widow. Saved by law from the pyre, but condemned by opinion and custom for the remainder of her days literally to sackcloth and ashes and the lowest drudgery in the very household where once, perhaps, her will was law, this manufacture spares her from being a charge on her family; she can always earn her bread. Among these causes will be discerned the very low prices at which gunny manufactures are produced in Bengal and which have attracted the demand of the whole commercial world. There is, perhaps, no other article so universally diffused over the globe as the Indian gunny bag. All the finer and long-stapled jute is reserved for the export trade, in which it bears a comparatively high price. The short staple serves for the local manufactures, and it may be remarked that a given weight of gunny bag may be purchased at a similar weight of raw material, leaving no apparent margin for spinning and weaving."

The entry of Dundee into the trade goes back to the year 1838, but this attempt was neither serious nor successful. However, the experimental stage of inexperience and failures gradually disappeared, and the next fifteen years saw spinning and weaving of jute carried on in Dundee with success and profit. In 1855 a beginning in spinning and weaving was made in Calcutta in earnest, and a mill was erected at Rishra, near Scrampore, which produced an out-turn of some eight to ten tons a day. Four years later the Barnagore jute mill came into existence and seriously commenced cloth-spinning on an extensive scale, and this same company is still going strong. In 1862 two more mills came into existence, the Gourepore and Serajgunge. The former is still in existence, and is one of the largest mills on the Hooghly. The Serajgunge mill, erected in order to be near the producing district for the raw material, was never a great success, and was finally destroyed by an earthquake in 1897, and its machinery and plant transferred to the Delta mills, near Calcutta. These mills reaped a great harvest of prosperity up to the year 1875. This attracted public attention, and there was a rush to erect new mills, no fewer than thirteen companies making their appearance. The inevitable result followed, and the next ten years was a period of depression owing to over-production. This led to a check in the building of new mills, and only one was added in the next five years. But in 1885 four more mills were added to the list, which remained stationary until ten years later, when extensions to existing mills and new mills increased the number of looms considerably. During this period considerable attention was paid to the export trade in gunnies and hessians, and great progress was made. Standards were established on a firm basis and the trade generally put on a sound footing. The marked improvement in the manufacture of hessians enabled the Calcutta mills to compete successfully with Dundee in the American trade. Since 1895 the expansion has been rapid, in spite of periods of depression and gloom. At the present time there are some forty-six mills on the River Hooghly, with a total of close on 40,000 looms, employing very nearly a quarter of a million Indian laborers, having a capital of over £13,000,000 (including debentures and reserves), and using three-quarters of a million tons of coal per annum. The prosperity of the industry at the moment is extraordinary, and it is not easy to see what can happen to shake this trade, which is being conducted on the soundest commercial lines.

Combined Concrete and Tile Construction

The recently patented Poyet method affords an ingenious combination of reinforced concrete and special brick, and it allows of carrying out various building operations with ease and economy. It is unusually well adapted for floors of buildings, walls or partitions and similar work, and has already been applied with success in France. The process is based on the use of a special flat brick or tile of rather large size and somewhat over 1 inch thick. Such bricks, or rather tiles, are made hollow after the usual method for hollow bricks, and are practically flat on the under side, while the upper side carries four ridges along the length of the brick in the shape of dovetail tenons. At the edge, the brick carries a longitudinal groove of semi-circle section, and by placing two bricks together, the combined edges form a circular section space which is filled in with cement mortar to make the joint, while at the same time a ¼-inch reinforcing iron is laid in the middle of this joint. The joint groove runs parallel to the tenons. In principle, a continuous surface is made by joining up various rows of bricks in this way, the whole set being held together by the joints and the reinforcing irons, which latter are continuous over the desired length. The method will be well understood by observing the plan which is used for building a flooring. An under-support is erected consisting of scantling which is spaced some 3 feet apart and runs along the whole floor area. Between the timbers is a sliding plank upon which the brick surface is laid which goes to form the ceiling, and by the above method the whole area is laid with such brick. At each scantling is constructed a combined concrete and brick member or longitudinal floor-beam. Each side of the beam consists of a single brick row set on edge with tenons inward and horizontal, and joined as before. Two good-sized reinforcing irons are laid in the space between bricks, and concrete is flowed in so as to make the combination beam, which thus has a brick plating on each side. Upon the beams is laid a second tile flooring similar to the underlying one, and the air space between the two floors is of course equal to the height of the brick, or about 8 inches. However, the upper flooring of tile is not continuous, but is interrupted at each beam so that the mold lies open at the top. Over the whole is laid a concrete floor surface, and in reality all the concrete work of members and floor can be put in at the same time, after the brickwork is all in place, that is, concrete is flowed into the members (molds) and then over the top or floor surface. The upturned tenons hold the concrete to the brick of the floor. As to the under surface which forms the ceiling of the lower story, the tile are striated somewhat instead of carrying a smooth surface, so that ceiling plaster can be applied with good adherence. The advantages of the Poyet system are numerous. It can be used with the Hennebique or other reinforced concrete methods, and it will be seen that the scaffolding work is of the simplest nature. A very rapid construction is obtained without elaborate false-work, and the hollow brick make an air cushion which is soundproof. The method is also valuable for terrace or under-roof apartments as it avoids accumulation of heat. Side walls are made by setting up rows of brick to form a hollow wall or mold which is filled in with concrete, this being well held by the inwardly turned tenons. The hollow brick method affords air spaces which are used for running various pipes or electric wiring. Such construction is fireproof and is of light and economical makeup.

Patent Applications in Great Britain

How far the war has curtailed the number of patents applied for may be seen from the fact that last year only 18,191 applications for patents were received—6,629 less than in 1914 and the lowest number received in any year since 1887. Women inventors, too, were fewer, the 268 applications representing a decrease of 79. Every application for a patent relating to munitions of war has to satisfy the Comptroller-General that the publication of the invention or design will not aid the enemy, and the Admiralty and the Army Council have to be consulted. The number of documents relating to foreign patents, designs and trade-marks deposited for record fell from 815 to 268. There were 93 notifications in respect of Germany; Austria, 51; Hungary, 29; Turkey, 14; France, 14; Russia, 3; and Italy, 2.—*The Practical Engineer.*

A Comparative Color Photometer*

A New System for the Standardization and Charting of Colors and Also for Scientific Color Synthesis

By Arthur Howland

THE photometer is essentially a light tight box with a slide in the front having a small opening through the aperture of which the operator sees the absolute black of the interior. It contains a small high speed motor with a shaft arranged for clamping disks of paper or thin cardboard, which may be spun close behind the opening. The motor is screened from view by a second partition covered with black velvet, while a third screen back of the motor aids in absorbing any light rays which might otherwise find their way to the black velvet which covers the back of the box on the inside. By this method the background is so completely screened that the effect on looking into the opening is one of absolute black. In

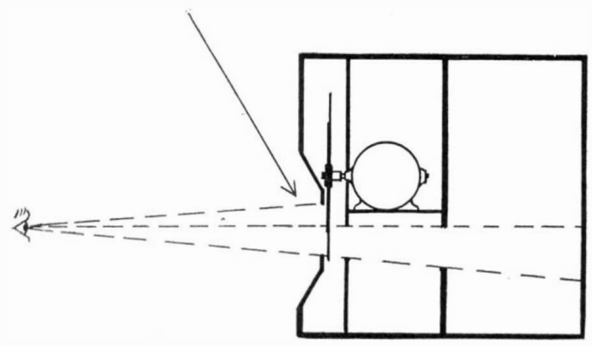


Fig. 1.

operation, the machine should be so set up that light will enter only in the direction indicated by the arrow in Fig. 1, while the operator should stand directly in front of the box with his eye at the level of the opening and about 15 feet away.

Sectors of all sizes from 0 to 100 per cent similar to those shown in Fig. 2 are provided, with ends carefully

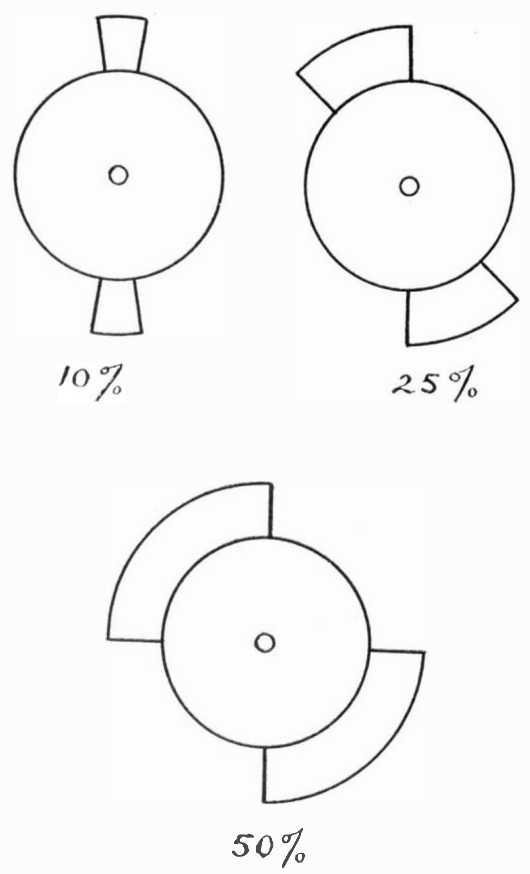


Fig. 2.

coated with magnesium carbonate. Colored sectors of the same pattern are furnished in a few of the strongest colors obtainable.

With this outfit it is then possible to produce practically all known colors in every conceivable strength or luminosity. Mixing a white sector with the black of space gives an absolutely pure neutral gray of any desired luminosity as set by the size of the sector chosen, from a blacker black than any known pigment to a purer white than has ever been produced in papers or pigments.

*Science Conspectus.

Mixing a colored sector with the black of space gives the deeper shades of the same color or by using the white sectors in conjunction with the colored ones it is possible to make grayer or lighter tones of the same color. Again, by combining any two of the colors provided in this same way it is a simple matter to produce any color desired within the limits set by the strength of the working colors used. To make the machine of practical value, it is necessary to discover very strong and pure colors.

Also it is quite essential that the colors be laid upon the sectors with an absolutely colorless medium, as any oil or varnish vehicle would tend to discolor them to a marked degree.

After fully two years of research work such colors have been obtained and a method of applying them to fine white card stock has also been found. If at any time stronger colors are discovered they will simply increase the range of usefulness of the apparatus to within their own limits of strength.

Since all possible combinations of color may be made with this photometer, it is practically an easy matter to study the geometrical relationship of pigment colors with a view to charting them for commercial as well as educational purposes. Incidentally it has been found practical to place them with such accuracy that all combinations may be figured mathematically by using the three properties of color—hue, strength, luminosity.

THE CHART.

The photometer is best used in conjunction with a chart which might well be called a "colorless" color chart (see Fig. 5) since there are absolutely no colors upon it, although every point of its entire surface may represent a different color or varying luminosities of the same color for any one spot.

It has long been known that every color has its opposite or "complementary" color, the combination of which will always give gray if spun in the proper proportions for exact neutralization.

By imagining each color as projected down upon a horizontal plane, we are enabled to use ratios of distances between them just as easily as if it were possible to take the measure of the actual distances in space. To illustrate: If R (Fig. 3) is a certain red situated above a given plane and R' is its projection upon that plane, and if G and G' are respectively the position and the projection of a certain green, then if we wish to make a color Y intermediate between R and G, it is only necessary to spin the red and green disks together in the ratio of a' parts of red to b' parts of green to get the resultant color Y, which in this case is a dull yellow, since a' is to b' as a is to b. (In this case 3 to 5.) Suppose that our red has a luminosity of 27 per cent of that of our standard white and that the green has a luminosity of 25 per cent, then to figure the resultant color, we use the following form:

Area	Luminosity
R 37.5 per cent	0.10125
G 62.5 per cent	0.15625
	0.25750

This means that the resultant color, yellow, has a luminosity of 25.75 per cent if made from the red and green above mentioned.

To produce this result the disks should be set as shown in Fig. 4.

All known colors may be placed about a neutral axis in space and will actually respond with mathematically exact spinning ratios to the above method of procedure, provided they be properly located in their true positions according to their three properties of hue, strength and luminosity. By knowing the luminosity of the comparatively few working colors on the prepared disks and sectors, it is a very easy matter to figure them out beforehand what color will result from any possible combination.

As there are endless combinations that can be made, it is also possible to figure combinations of other colors that will produce identically the same resultant and the color photometer will actually permit of making both at the same time. For an example: Take the above red and green in the proportions given to make a dull yellow. At the same time spin sectors of a strong yellow and white (with the black of space) on the same shaft with the red and green. (Fig. 6.)

If the proportions of all of these colors used are taken from the horizontal chart as figured from the point where the lines between the components cross, it is an easy matter to figure both sets with such accuracy that the two combinations will match absolutely even though it may never have been done before.

If a strong yellow Y (Fig. 5) has a luminosity of 80 per cent, and the chart shows a ratio to the meeting point Y' of say 18 per cent of the yellow to 82 per cent of neutral gray N (black and white) the equation would stand as follows:

$$\left.\begin{matrix} R\ 37.5 \text{ per cent. } 0.10125 \\ G\ 62.5 \text{ per cent. } 0.15625 \end{matrix}\right\} = \left\{\begin{matrix} Y\ 18 \text{ per cent. } 0.1440 \\ N\ 82 \text{ per cent. } 0.1135 \end{matrix}\right.$$

$$0.25750 \qquad\qquad 0.2575$$

Therefore the colors Y' would be identical, since their position on the chart indicates their similarity of both hue and strength, and their luminosities are both 0.2575 as compared with the same standard.

These, of course, are very simple examples of what may be done with the machine in an educational way, but they lead to very remarkable possibilities with the refinements that are bound to come in the future.

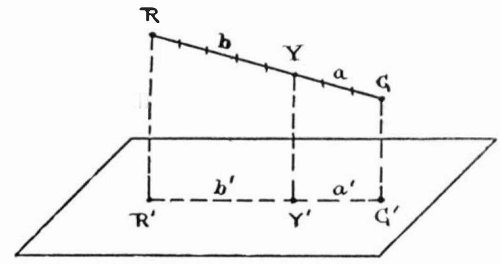


Fig. 3.

It is always possible to retain a sample of the working colors in the dry powder form, which if kept in the dark in glass containers will not fade or change in any manner, so that they will always give a standard with which to work. If, then, a color is once matched to the standard made from these working colors, it is always possible to produce again the same standard from these working colors by taking some of the dry color which has been kept under proper conditions and placing it upon fresh disks and sectors. Manufacturers abroad could have working colors from the same pigments as standards and could reproduce any point upon the chart that might be indicated by American distributers. Such points could be indicated in several ways with great accuracy. While the actual percentage of each working color used in any given case might be easily cabled, a better way would be to designate each color wanted by three numbers indicating in order, the hue, the strength and the luminosity.

The three numbers, 23, 49, 31, for instance, stand for one color only, namely, a red R (Fig. 5) whose hue is 23 per cent of the angular distance from a point of lowest

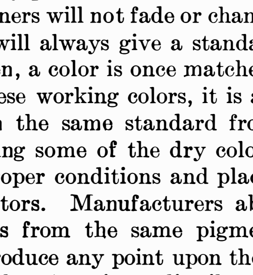


Fig. 4.

luminosity in the circle of spectral hues taken as 0, whose strength is represented by 49 units of distance out from the neutral point N, and whose luminosity is taken from comparison with the standard white used and is found to be 31 per cent.

An American manufacturer can match a piece of goods to his combination of sectors, locate it upon his own chart and cable the result to Paris or London, to any house that has a similar outfit, with the certainty that under the same lighting conditions an absolute match will be obtained. Under ordinary conditions daylight from a north skylight will give satisfactory results, but for very accu-

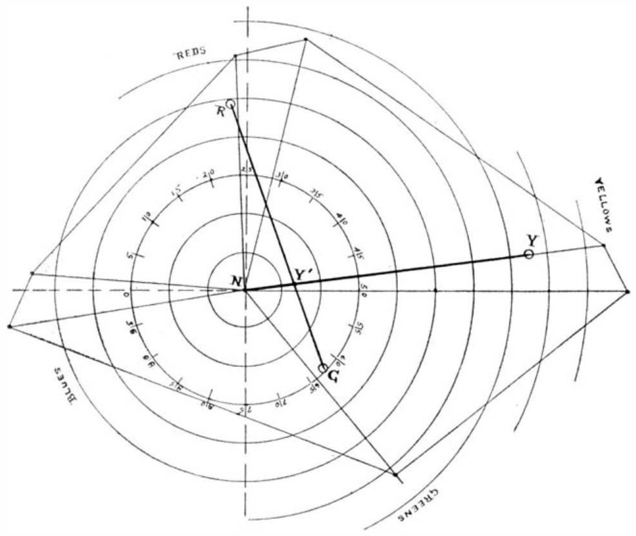


Fig. 5.

Fig. 5.—The diagram represents the "plan view" of an imaginary color solid containing within its limits practically every known pigment color. The reader may be considered as above the drawing looking down upon the highest point of the solid at *N*, which point represents the upper or white end of the neutral axis containing all possible grays from absolute black to white. The lower or black end rests upon the plane of the paper.

Each of the limiting points of the diagram may be considered as the projection upon the plane of various colors of great strength whose hues vary with their angular positions about *N* in exact accordance with the order of the spectrum through red, orange, yellow, green, blue, violet, and whose positions above the paper are fixed by their respective luminosities. Their relative strength is indicated by their distances from point *N* radially outward as 10, 20, 30, etc., and is determined by the concentric circles. Note that between the blues and the reds will be found all purples which are seen only in spectral colors when spectra overlap, the violet end of one with the red end of another.

While the placing of colors upon a chart in this manner is purely an imaginary one, it is nevertheless a fact that when properly placed they will respond with marvelous accuracy to exact laws of combination which this figure portrays. As soon as three color points have been determined, all other colors must then occupy fixed positions with respect to them.

Such colors will then obey the law of moments of forces with mathematical accuracy where the spinning area times the strength of one will always equal the spinning area times the strength of the other when opposed to each other as complements.

Moreover, when once a few strong colors have been properly located upon this chart, it is then possible to figure in color and solve problems mathematically, predicting the exact resultant color in all three of its properties of hue, strength and luminosity.

It will be noticed that the diagram is very nearly a true parallelogram, with the four colors red, yellow, green and purple-blue at the four corners. It should, then, be possible to produce all colors lying within these bounding points from a combination of these four with black and white. That such is actually the case, may be most beautifully demonstrated by the use of four such powerful working colors in the photometer described above.

rate matching it will be found that it is better to do the work by the aid of an incandescent lamp outfit with a screen and voltage regulator similar to some of those now upon the market for this very purpose.

Educationally, the photometer should be a wonderful aid to teachers and supervisors, who would be able to illustrate to their classes the exact composition of any given color, the relation of one color to any other, the harmony of different hues of the spectral circle, the complete separation of luminosity from hue or strength, and last, but not least, the fascinating process of producing new colors that have never been equaled in pigments.

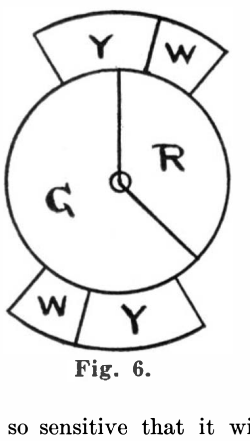


Fig. 6.

The machine is so sensitive that it will analyze even a black pigment, showing with great accuracy the percentage of red or blue or green that is in it and making it possible to correct it to a completely neutral black.

There is probably no manufacturing process to-day that does not use color in some form and it will undoubtedly be used even more generally in the future when some such standard will come into general use throughout the civilized world.

Place of Greatest Safety During Thunderstorms

The question is often asked as to the location of greatest safety during a thunderstorm. In this respect it may be said that there is no place or object in the path of a thunderstorm that is not liable to a stroke of lightning. Places or objects may be more or less liable to a stroke of lightning according to their relative exposure, etc., but no place in the path of a thunderstorm is to be considered as one upon which a stroke of lightning is not likely to fall. The location of complete safety during a thunderstorm is, therefore, one in which, even though a stroke of lightning does fall upon it, no harm will come to the occupants. From what has been said in the foregoing portion of this paper, it is evident that such a location may be found only in a space entirely surrounded by a metal network, in a steel-frame building, or in an underground chamber. With the exception of places similar to these three, there does not seem to be any place where absolute safety may be obtained. The next degree of safety is undoubtedly to be found in houses or other buildings which are protected by lightning rods, but, although the degree of safety which can be attained by using rods may be very high, the risk can not be entirely eliminated.

In the event of a stroke on an unprotected building there is considerable danger to life, but there is no doubt that an unprotected house is preferable to the open, under trees, or in unprotected outbuildings. As heretofore shown from the news clippings in H. F. Kretzer's Lightning Record, when a stroke falls on an unprotected house sheltering a family of the average number of persons, the minimum chances of escape are 45 in 100. In all probability, however, the chances of escape are much greater than this. In 254 instances of casualties in unprotected houses which are given in this record, there were 117 cases of death and 137 cases of injury. From the same source it is found that in 153 cases of persons struck in open fields, 116 were killed and 37 were injured. In 9 cases of persons struck near wire fences, 8 were killed and 1 injured. It seems, therefore, that it is far better to take shelter in a house which is not protected against lightning than to take chances in the open, where everything is damp and hence the liability to shock or injury far greater than than in a dry place.

The news reports just mentioned show that when unprotected houses are struck, people are injured or killed in almost every conceivable location in the house. It seems that there is no place in a house to which lightning will not penetrate, although many statements to the contrary have been made. Some places in a house are undoubtedly more dangerous than others, however, among such places being the vicinity of stoves, places between masses of metal on the exterior of the building, and metallic masses in the interior of the building, whether earthed or not, and near chimneys. An example of a place between metallic masses of the character of those just mentioned would be between a down spout and a steam or hot-water radiator. Other dangerous places in a house during a thunderstorm are at telephones, or touching screen doors or other metallic bodies which connect with the exterior of the building.

Out of doors the most dangerous places are evidently in open fields, under isolated trees, and near wire fences. Small sheds and other shelters are almost equally as dangerous as isolated trees, especially if the sheds are in the open, away from larger buildings. Thick timbe ris undoubtedly the safest place to seek out of doors, for the reason that a single tree under which a person might take shelter in a forest area is not as likely to receive a stroke as a single object or a person in an open space of equal area.—*Technological Papers No. 56 of the Bureau of Standards.*

Do You Know That

Light promotes cleanliness?

A clean mouth is essential to good health?

Physical training in childhood is the foundation of adult health?

Isolation is the most efficient means of controlling leprosy?

Headache is Nature's warning that the human machine is running badly?

Bullets may kill thousands—flies tens of thousands?

Efficient muzzling of dogs will eradicate rabies?

The protection of the health of children is the first duty of the nation?

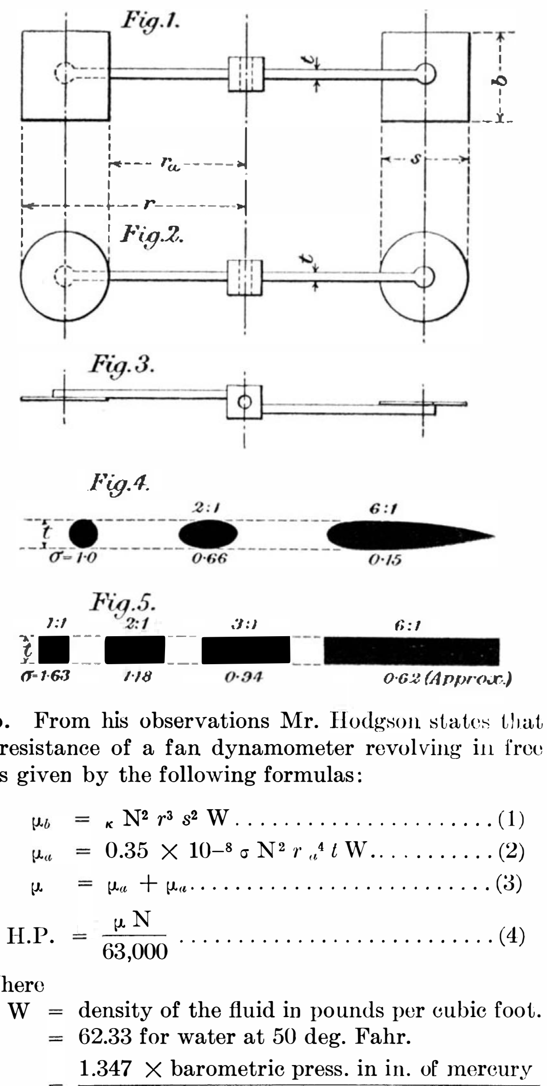
Bad temper is sometimes merely a symptom of bad health?

In the lexicon of health there is no such word as "neutrality" against disease?

The death rate of persons under 45 is decreasing; of those over 45 it is increasing?—*The Pacific Medical Journal.*

The Fan Dynamometer

For certain purposes the fan dynamometer is exceedingly convenient, but it has not hitherto been regarded as an instrument of precision. Some interesting experiments made with the object of removing this reproach were described in a paper read before the Institution of Automobile Engineers by Mr. J. Lawrence Hodgson. In the majority of these experiments the fan used was revolved in water, but some tests were made in air, and a comparison of the two showed that both sets could be represented by the same formula, on assuming that in each case the resistance was proportional to the density of the fluid. Two forms of fan were used by Mr. Hodgson, of the shapes shown in Figs. 1, 2, and 3. The fan, it will be seen, consisted of a square or round paddle mounted at the end of a relatively thin arm. The section of this arm was in some of the experiments round and in others of the shapes shown in Figs. 4 and 5. The experiments showed that the resistance depended, to some extent, upon the proportion of $\frac{r}{s}$ (see Figs. 1 and 2), but that once this ratio exceeded about 7 to 1 the resistance was practically unaffected by a further increase in the ratio.



From his observations Mr. Hodgson states that the resistance of a fan dynamometer revolving in free air is given by the following formulas:

$$\mu_b = \kappa N^2 r^3 s^2 W \quad (1)$$

$$\mu_a = 0.35 \times 10^{-8} \sigma N^2 r_a^4 t W \quad (2)$$

$$\mu = \mu_a + \mu_b \quad (3)$$

$$H.P. = \frac{\mu N}{63{,}000} \quad (4)$$

Where

W = density of the fluid in pounds per cubic foot.
= 62.33 for water at 50 deg. Fahr.
$= \frac{1.347 \times \text{barometric press. in in. of mercury}}{(460 + \text{temp. Fahr.})}$

μ_a = torque due to arms in inch-pounds.

μ_b = torque due to blades in inch-pounds.

μ = total torque.

H.P. = horse-power.

N = revolutions per minute.

s = length of side of square, or diameter of disk in inches.

r = external radius of fan in inches.

r_a = radius of arm in inches, measured to inside of blade.

t = thickness of arm in inches.

κ = a coefficient which when $\frac{r}{s} > 7$ is about 2.04 for square blades and 1.58 for round blades.

σ = a coefficient depending on the section of the arms as given in Figs. 4 and 5.

When the ratio $\frac{r}{s}$ was less than 7 the resistance varied considerably with this ratio, being for square blades about 2.07 for $\frac{r}{s} = 6$; 2.27 for $\frac{r}{s} = 3$; and 2.15 for $\frac{r}{s} = 2$. The corresponding values for circular blades are 1.58 for $\frac{r}{s} = 6$; 1.68 for $\frac{r}{s} = 3$; and 1.63 for $\frac{r}{s} = 2$. In practical work Mr. Hodgson says that the diameter of the flywheel to which the fan is bolted should be less than r_a, and the blades should clear the floor by at least 1½ times the radial width of the blade, and that there should be a distance of 1½ fan diameters between the plane of the fan and any adjoining wall.—*Engineering.*

The Metallurgy of the Rarer Metals*

Whose Cheap Production Offers an Attractive Field for Research

By Joseph W. Richards, Lehigh University

There are many metals which may be called "the rarer metals." Among them the most interesting by far, to the metallurgist and to the economist, are those metals whose compounds are relatively cheap but which command a high price because of the difficulty of their reduction. These are the metals whose market price may at some time be reduced one half, three quarters, perhaps nine-tenths, by improved methods of reduction, and the discussion of how this might be accomplished and to what uses these metals at such low prices might be put, is interesting to the border of fascination.

If this article were being written thirty years ago, aluminium would be one of the metals to be discussed. It is now out of that class, but in 1886 it was one of the rarer metals, selling at $10 per pound, although its ores were "as common as dirt." At that time you could buy a ton of bauxite ore containing 6/10 ton of alumina or 3/10 ton of aluminium for $5, while the 3/10 ton of aluminium was being sold for $3,000, at wholesale. Or, eliminating the purely chemical work, 6/10 ton of chemically purified alumina could then have been bought for $50, while the aluminium it contained was worth on the market sixty times that amount. Such were the metallurgical conditions in the aluminium industry thirty years ago, and so attractive were they to experimenters and inventors that the genius of the profession expended its best talents on the problem, with the result, in less than ten years, of reducing the market price to less than one tenth its former figure.

The silicon industry furnishes another example in point. Silica is the most abundant and cheapest material in nature, yet silicon was selling in 1900 as a chemical curiosity at *over $100 an ounce.* Imagine the stirring up which my metallurgical wits received, when in 1902, Mr. Tone, at Niagara Falls, showed me a barrel full, 100 pounds perhaps, of silicon made in his electric furnace, and asked me what uses it could be put to. At the present time, 10 cents per pound is a good market price for silicon, which is often sold by the carload.

It is such seeming fairy tales as these which constitute the fascination of those metals which are abundant in nature but whose high cost rests on the difficult and costly methods of reduction employed. Such opportunities exist, for our rising generation of chemists and metallurgists to make themselves famous and, incidentally, rich—but they will find their fame more of a reward than their riches.

Among the metals at present of high price, but which by improved metallurgical processes might be made very cheaply, are beryllium, boron, magnesium, calcium, strontium, zirconium, molybdenum, barium, titanium, chromium and cerium (mixed metals of the cerium group).

BERYLLIUM.

Commencing with one of the light, alkaline-earth metals, its ore is not as rare as is ordinarily supposed. Most non-mineralogists link it with beryl, and think of the latter as a very pretty and very expensive gem—the emerald. But the emerald is only the clear green or aquamarine stone, while massive beryl, looking like massive green quartz, is much more common, and is even abundant in some localities. The beryl crystals of Acworth, N. H., are sometimes as large as a barrel, and the massive beryl at this locality is quarried like feldspar. Its composition is

SiO_2	67.0 per cent
Al_2O_3	19.0 per cent
BeO	14.0 per cent

It is difficult to say what the price of this material would be if it was desired by the ton, but it should not be expensive. When chemically treated, both the Al_2O_3 and the BeO which it contains could be separately obtained.

Up to the present, no one has succeeded in isolating the metal except by reducing a halide salt of beryllium by potassium or sodium (Bussy, Wöhler, Debray, Menier, Reynolds, Nilson and Petterson, Kruss and Moraht) or by electrolysis of double chloride, bromide, or fluoride of beryllium and sodium or ammonium (Borchers, Warren, Lebeau, Liebmann).

These methods are tedious and costly for two reasons: First, they require the conversion of the beryllium into an anhydrous halide salt, which is a difficult chemical operation, and, second, the electrolysis sets free the halogen, which is very destructive of electrodes and apparatus. It is not to be expected that beryllium can be made cheaply until someone masters the direct electrolysis of the oxide, dissolved or suspended in a more stable melted salt. This is by no means an impossibility; a similar solution was found for the aluminium problem, and systematic, determined search would in all probability find the answer for beryllium. In such a case, the cost of the metal would depend only on the cost of beryllium oxide, being probably not more than 20 cents per pound plus the cost of the oxide. Since BeO is only 36 per cent Be, it would require 3 pounds of oxide to give one of metal; if the oxide cost 10 cents per pound, the total cost of the metal should not exceed 50 cents, by such a supposition process. Dealers in rare chemicals will charge you, at present, $300 per ounce for a specimen of it.

Lebeau has produced beryllium bronzes by reducing directly, in the electric furnace, a mixture of beryllium oxide, copper oxide and carbon; 0.5 per cent of beryllium makes copper hard and sonorous; 1.5 per cent makes it yellow, and 5 per cent makes a fine golden yellow bronze.

Beryllium, like any other rare metal, must find uses which justify its cost. Being white, malleable and unchanged in air, its specific gravity, 1.64, would make it particularly useful for objects where great lightness and permanence in air is the first consideration and cost secondary. So far we practically know nothing about its tensile strength or rigidity, about how it might be strengthened or stiffened by small additions of magnesium, or aluminium or even of zinc, or copper, or manganese, or some other metal. We do not yet know the mechanical properties of its fine bronzes, except that they are somewhat similar to aluminium bronze, but in what respects they might be superior or perhaps unique is unknown. Finally, the metal may easily possess special properties, now unknown, which may render it particularly useful for some specific purpose. Its specific heat, for instance, is the highest of any useful metal, and its latent heat of fusion must be abnormally high, possibly 300 calories, and its latent heat of vaporization probably higher than that of any known element except carbon or boron. Such characteristics might give it special uses in electrical instruments or for physical apparatus, where its cost would not exclude its use. Altogether, beryllium is a metal which will well repay extended metallurgical research and minute physical and chemical study of its many unique properties.

MAGNESIUM.

The metallurgist has been coquetting with magnesium for half a century, and has, as yet, not made a fraction of the progress which he should have made. We can get its oxide cheaply and in abundance, its salts are not very difficult to prepare, we know their properties to a considerable extent, we know almost all the properties of the metal which bear on its isolation, and yet the industry lags and halts as if there were no such thing as modern metallurgy. To prepare by tedious methods the anhydrous double chloride, and then to electrolyze it about as Matthiesen did fifty years ago, is nearly all that can be said with certainty about its present metallurgy. At any rate, using magnesium oxide costing a few cents per pound, the metal sells for about as many dollars per pound, and yet there is a great scarcity of the metal.

Dr. W. M. Grosvenor, in a recent paper before the American Electrochemical Society, summarizes the present methods of production and the uses of the metal. Happily he also suggests the great field open for improvement, especially for radically new metallurgical methods of production. With magnesium in its salts costing less than 8 cents per pound, he places the actual cost of the metal at $1 per pound, leaving over 90 cents per pound for the cost of its extraction. "Brethren, these things ought not so to be." Speaking with the enthusiasm born of past achievements in electrometallurgy, along entirely analogous lines, a modern, up-to-date attack on this problem ought to result in producing magnesium at 25 cents per pound.

The point of attack should be undoubtedly to reduce the oxide directly. The halogen salts are hygroscopic, and the halogen is destructive of the reducing apparatus. It is almost certain that proper research will enable the electrometallurgist to feed MgO directly into an electrolytic bath of fused salts and take magnesium or magnesium alloy from it. The pure metal will float on almost any fused salt, but its alloy with heavier metals may be made such as to sink, and many of its alloys have immediate useful applications.

Dr. Grosvenor makes suggestive remarks about the reduction of magnesia by carbon. If the boiling point is only 1,200 deg. Cent., then a process of reduction similar to that of zinc oxide might be practicable if we could (1) find a retort material which will stand the temperature required (1,800 deg. to 2,000 deg. Cent.). and (2) condense the vapors without contact with air. Fortunately, magnesium does not form carbide at high temperatures, so that its reduction is simpler by that much. Dr. Grosvenor speaks of a chemical process which will use cheap raw material, a moderate amount of fuel, and give a fair efficiency of reduction. With all expenses added, he estimates a cost not over 35 cents per pound. This may be true, but whether it materializes or not, he and his colleagues have the right vision of the possibilities, I may even call them the probabilities, of this field; they are truly "absolutely fascinating."

While the world-war lasts, with its enormous demand for magnesium for military purposes, the price will remain in the dollars per pound. But experience in this line is being rapidly accumulated, and improvements are undoubtedly rapidly succeeding each other, although keen competition is keeping them secret as far as possible. After the war's close, with normal industrial conditions reappearing, magnesium will undoubtedly sell at a price which will take it out of the class of the rarer metals and put it among the common ones. As the price goes down its industrial uses will increase in a geometric proportion, and instead of production being expressed in thousands of pounds per year it will reach thousands of tons. This will be another of the by-products of the great war's stimulus to metallurgical industry.

The possibilities held out to the metal industry by reasonably cheap magnesium are extremely interesting. The stiffening of magnesium to produce strong alloys with specific gravity not over 2 has not been properly studied. It is quite possible that alloys analogous to *duralumin* may be discovered, as strong as soft steel and only 30 per cent of its weight, which will find extensive use in aeroplanes and dirigibles. Such alloys may also largely displace aluminium alloys, which are used by thousands of tons annually in the automobile industry, with a saving of one-third in weight, which will compensate for a higher first cost. The metallurgical uses of magnesium will also be greatly extended by its lower price, such as for deoxidizing brass, bronze, nickel, monel metal, since it is a much stronger deoxidizer than aluminium. In fact, aluminium has blazed the way into numerous uses for which magnesium, as soon as it becomes cheaper, will compete and replace its older sister. With supplies of magnesium ore as plentiful as those of aluminium ore, and the metallurgist awake to his responsibilities and producing the metal cheaply, there will inevitably be a large future for magnesium as one of the common metals of every-day life.

CALCIUM, STRONTIUM, BARIUM.

These are a trio of highly interesting elements, common enough in nature, but all scarce and of high price because of the metallurgist's lack of efficient and cheap methods of reduction. With burnt lime, CaO, one of the cheapest of common materials, strontium sulphate, a mineral found in considerable abundance, and barium sulphate, so common, as heavy-spar, that it is used as an adulterant for some cheap paints, the metallurgist is again faced with the demand for cheap methods of reduction. And yet, although calcium is sold at a few dollars a pound, strontium and barium cost several dollars per ounce. Here is a two-fold need: first, cheap production; second, a thorough study of these metals to find out their specific properties and their particular uses. Which should be undertaken first is an interesting topic for discussion. Historically, the metallurgist has usually produced the metal first and then studied its properties and possibilities; at present, with these metals already at hand, metallurgical activity might be greatly stimulated by extensive studies of the properties, alloys, and chemical uses of these elements. Our present information in this direction is fragmentary

*A paper read at the Cleveland meeting of the American Institute of Chemical Engineers on June 14, 1916.

and partly unreliable as far as it goes. A Carnegie Research scholar, or even the Bureau of Standards, by disclosing to us some of the unknown properties of these elements, might stimulate the experimenter to renewed efforts to find cheaper methods of reduction.

Calcium, at the present time, is the best known of these three elements. The method of electrolyzing its fused chloride and lifting the metal away from the surface, as an irregular stick, has been fairly successful, and since the chloride is not difficult to dehydrate, the whole operation is not very expensive. Calcium is therefore, at present, perhaps a semi-rare metal, which could be produced much cheaper even by present methods if made on a large scale to fill a large demand. The method of production is easily susceptible of minor improvements, and the chlorine is a valuable by-product to the manufacture. The principal hitch at present is in finding the uses for a large production of calcium. Here is where extensive study of the properties and possible uses of calcium would greatly stimulate the metallurgical industry. With specific gravity of 1.85, its possible alloys with other light metals should be exhaustively studied; quite possibly some of them are strong, resistant to air and water, perhaps even to acids. Calcium tarnishes easily in the air, and magnesium also, but it is quite possible that some alloy of the two does not tarnish, and may have valuable mechanical properties. Another large possible use is as a chemical purifying agent in melting and casting metals. Calcium-silicon-aluminium alloy has already found application as a deoxidizing agent in steel, because while aluminium oxide and silicon and their combination with each other are infusible at steel-melting temperature, and therefore are eliminated slowly from the metal, calcium oxide forms with these an easily fusible slag, which easily rises out of the molten metal. It is quite possible that a small addition of metallic calcium may in a similar manner reduce the amount of sulphur and phosphorus in steel, because it is either as calcium sulphide or calcium phosphate that these elements are eliminated in refining steel. Other metals and alloys whose properties are damaged by sulphur or phosphorus may be similarly refined or improved. The alloys of calcium with copper, tin, bronze, brass, monel metal, and other commercial alloys have not been studied; until they are, no one knows how many useful mixtures may exist with particular properties of industrial value. The question of adding calcium to the light stiff aluminium alloys, for instance, is worthy of attention, but has not been touched.

Strontium is a silvery-white, very soft metal, with properties similar to calcium, density 2.54. Its ores cannot be called rare minerals, and it is a rare metal, therefore, only because of the difficulty of its isolation. It is chemically very active, and electrochemically extremely hard to manage. It has about the same specific gravity as its fused salts, so that it neither rises nor sinks in any of them quickly; it seems also to redissolve in its melted salts with great velocity, so that very high current density is required to obtain any metal at all. Its surface tension appears to be abnormally high, so that it separates out in more or less minute globules which are highly indisposed to running together into one mass. What an attractive subject this forms to the electro-chemist who really wants to meet difficulties and taste the joys of overcoming them. And then one may well ask: To what purpose? Here, again, we do not know, but we can feel confident that in the innumerable list of possible combinations of metals strontium might have properties different from any other element, which would lead to its employment on a large scale. These are all questions of the future which form the undiscovered country open to the investigator and chemical pioneer. We may well thank our stars that the world of science still holds unexplored areas to tempt the adventurous investigator and to reward the *Wanderlust* of the metallurgical pioneer.

Barium is common in its compounds and almost unknown in itself. Under electrolytic conditions where calcium comes out *en masse*, and strontium separates as small globules, barium is obtained only as a fine powder. Its density is 3.75, but its salts are heavier than the corresponding strontium and calcium salts, so that the fine powder may sink or swim, largely according to the temperature. And yet the fused barium salts are very decent and manageable salts, easily obtained anhydrous and melting cleanly. Their electrolysis, however, is nearly the most difficult task that the electrometallurgist can take up. But it should be taken up and mastered, because a metal so common in its compounds could be obtained in large quantities if uses for it were developed, and if our modern electrometallurgists are worthy successors of Faraday, Bunsen and Castner, they should vigorously attack the problem of its cheap extraction. Even if their end was not reached, they would be whetting their metallurgical wits upon the finest of chemical whetstones, and their experiences would be of value to themselves as well as to other lines of electrometallurgy.

BORON.

As an intermediate element, semi-metal, cheap and abundant in its compounds yet almost unknown as an element, boron is very interesting. Although quoted at several dollars an ounce, yet there are possibilities of it being made for x cents per pound, where x may be anything over 25. It is only the prophetic prescience of the enthusiastic metallurgist, however, that can discern this goal in the distant future.

Boron occurs in nature as its oxide, sassolite, containing 31 per cent of boron; as borax, containing 11.5 per cent of boron, and as colemanite, containing 18.9 per cent of the metal. These sources are comparatively abundant, the oxide being found in volcanic districts, borax near dried-up lakes, and colemanite (calcium borate) being literally a waste product of the borax mining for which no use has yet developed.

Gay-Lussac and Thenard, Wöhler and Sainte-Claire Deville reduced the oxide by potassium or sodium, other chemists by phosphorus, magnesium, aluminium and calcium, while Duncan reduced boron chloride gas by hydrogen. Chemically, its reduction does not appear to be of extraordinary difficulty. Electrochemically, Davy electrolyzed fused boracic acid, Gores potassium borofluoride, and Faraday fused borax. All describe having isolated boron. Quite recently, Weintraub has decomposed boron chloride by hydrogen in a high-tension arc, and obtained purer boron and in larger quantity than any previous investigator. His classical paper is in the *Transactions* of the American Electrochemical Society (1909) 16, 165.

The properties of the pure boron obtained by Dr. Weintraub are exceedingly interesting. Its fusing point is extremely high, between 2,000 deg. and 2,500 deg. Cent.; it was fused in a boron nitride crucible under the pressure of its own vapor. Its boiling point is near to its fusing point; it has considerable vapor tension as low as 1,600 deg. Cent. It has a conchoidal fracture, and is nearly as hard as the diamond. At room temperature it is electrically almost a non-conductor, but at 500 deg. Cent. its conductivity has increased 2,000,000 times; at 1,000 deg. Cent. its conductivity is of the order of that of the metals. Applying moderate voltages to a cold piece, it soon warms up and makes itself a good conductor. Such extraordinary properties suggest its use for many interesting electrical contrivances, which are enumerated by Dr. Weintraub.

Other uses of boron, which have not yet been thoroughly investigated, are in the formation of boron steels and boronized copper. The former were investigated by Guillet, in France, with irregular results; in some respects, at times, the effects were similar to that of vanadium in the famous vanadium steels, at other times the results were different. The uncertainty may have been due to irregular composition of the ferro-boron alloy used. A great amount of investigation should be done on this line, first in making a reliable quality of ferro-boron, and second in using it systematically in various qualities of steel. The question of boronized copper is in a still greater state of uncertainty. Boron or even boron sub-oxide (B_7O, or perhaps boron saturated with B_2O_3) added to melted copper enables a perfect copper casting to be obtained of practically 100 per cent electrical conductivity; a trade product sold as boronized copper has similar effects in producing sound copper castings. These results are only the beginning of an extensive field of investigation of the effects of small amounts of boron on metals and metallic alloys. They will certainly lead to important metallurgical discoveries and improvements.

In metals and alloys boron can act chemically as a purifying or refining agent to remove oxygen, nitrogen, and perhaps sulphur, phosphorus, and dissolved oxides, while in larger amount it acts metallurgically as an alloying element. In the latter respect it forms true alloys, such as the ferro-boron alloy, which is an article of commerce. The possibilities of extensive use in molten metals and alloys are great, but mainly dependent upon systematic metallurgical research in properly equipped laboratories.

The production of the metal and its alloys also needs expert attention. For use in steel, a good uniform quality of ferro-boron is needed, and the manufacture of this in satisfactory uniform quality has not yet been mastered. Some years ago, the Pacific Coast Borax Company offered a prize of $500, to be awarded by the American Electrochemical Society, for a practical electric furnace method of producing ferro-boron directly from calcium borate (colemanite), a waste product of the borax mines. A few years later the prize money was returned by the society to the company as not having been earned, although several attempts were made at it. For use in copper, brass and bronze, a cupro-boron alloy answers as well as having pure boron. One method of making this is being tried, and the product is giving some very satisfactory results. Improved and more certain means of getting boron into copper are needed, and could probably be found by a moderate amount of careful investigation. As for pure boron, and the fascinating possibilities dependent on its remarkable properties, Dr. Weintraub's method makes the product, but at considerable expense, and a cheaper, easier method is a great desideratum. If such is found, boron will certainly occupy an important place among the useful metals.

CHROMIUM.

This element is also common and abundant in nature, and rare and expensive as a metal. Chromite, containing 34 per cent of chromium, costs normally $20 to $25 per ton, while the ferro-chromium alloy produced from it sells at $100 to $550 per ton, according to the per cent of chromium and carbon contained. But pure chromium, carbon-free, is produced only by reduction of chromium oxide by aluminium, and commands 75 cents per pound. The use of chromium in steel is rapidly extending to all varieties of extra hard and high-speed steel, but the use of pure chromium is limited by the high cost of its production and our lack of knowledge of how to handle it and of its possible useful effects. For example, chromium electroplating is white and durable, and for many purposes may be superior to nickel and almost equal to platinum plating, but the technique of always getting perfect plating has not been satisfactorily mastered. Cobalt-chromium alloys have been made which have some of the remarkable properties and uses of high-speed tool steel (stellite alloy of Mr. Haines). This is an excellent example of totally unexpected and valuable physical properties being discovered by systematic investigation. These alloys, however, must be made from pure chromium and not from ferro-alloy. How many other remarkable alloys yet remain to be discovered by patient and intelligent investigation no one knows or can even guess.

As for the methods of reduction, ferro-chromium alloy carrying high carbon (6 to 8 per cent) is produced quite cheaply in crucibles, cupola furnaces, blast furnaces, or electric furnaces. Low-carbon ferro-chromium commands three to five times as high a price, because of the difficulty of decarbonizing the raw product. It is very much to be hoped that tests will be made in the electric shaft furnace to see if it is not possible to produce directly from the ore a low-carbon product. The thing has been done in the case of pig iron, producing a low-carbon product which is called pig steel; there is no inherent impossibility in similarly mastering the conditions for producing directly the low-carbon ferro-chromium. The present prices of the two products, $100 and $500 per ton respectively, would warrant great efforts in that direction.

Similarly, chromium is not a difficult metal to reduce to the metallic state, but it is a difficult question to find the proper flux and to keep carbon out of it. Goldschmidt reduces it by aluminium; electrolysis of its fused salts is difficult because of their melting points. If electrolysis of aqueous solutions of chromium salts could be satisfactorily controlled, so as to produce heavy deposits, this might open the door at once to cheap and pure chromium. Electrolysis of molten relatively fixed salts in which chromium oxides are dissolved (similar to the Hall aluminium bath) is not a hopeless proposition. The chromium would be plated solid, however, on chromium cathodes, since the working temperature would be below the melting point of chromium.

The metallurgy of chromium is full of attractive possibilities, and the usefulness of pure chromium in the field of alloys is only beginning to be scratched; the scratching, however, is proving very much "worth while."

TITANIUM.

Our friend, Mr. A. J. Rossi, and the Titanium Alloys Manufacturing Company of Niagara Falls are the *alpha* and *omega* of the titanium industry. Nearly fifteen years ago my first introduction to Mr. Rossi was in the historic barn at Niagara, the cradle of so many of the Niagara Falls industries. Mr. Rossi was running the electric furnace and Mrs. Rossi was in the little laboratory making the necessary analyses.

Everyone knows of the enormous masses of titanic iron ore in northern New York and Canada, which contains so much iron and so little sulphur and phosphorus, that every blast furnace would be glad to get it if it was not for the titanic oxide, which makes it so unworkable that you could not give it away to them. Mr. Rossi tried first to extract the iron only, throwing away the titanium in the slag, but that was not profitable. He then turned to producing ferro-titanium alloy for use in steel and cast iron, and by indomitable perseverance has made that a success. A finely written booklet of over 100 pages, published by his company

and to be had for the asking, tells the whole story, so why take up time to rehearse it here?

In addition to titanium treatment of steel, to deoxidize and denitrogenize, this company also makes a specialty of titanium-treated aluminium bronze, also of titanium-treated bronzes and brasses of various compositions.

With titanic iron ore carrying 10 to 15 per cent of titanium as cheap as iron ore, and if iron-free material is required, rutile, 60 per cent titanium, at 5 to 7 cents per pound, there is no lack of cheap raw material. If uses are found for pure titanium, however, some other than the electric furnace must be used to reduce it, because, in absence of iron, titanium carbide would result. The methods for producing pure titanium are, like its prospective uses, still in the future, but they nevertheless are worth study and work. One can buy titanium metal now at about the price of silver, but if the problem were properly faced it could probably be made as cheaply as chromium.

MOLYBDENUM.

Molybdenum sulphide, MoS_2, 60 per cent molybdenum, looks almost exactly like graphite, and is about as widely distributed. Normally, it can be purchased as 90 per cent concentrates at 25 cents per pound. This would make the raw material for one pound of molybdenum cost nearly 50 cents; the selling price of the metal is about $2. This leaves a large margin to pay for reduction.

However, the principal need of the molydbenum industry is a better utilization of its sources of raw material. The deposits have not been, in general, properly prospected or opened up, and then not properly worked. They are usually low-grade propositions, with 5 to 10 per cent of molybdenite disseminated through hard rock. This calls for careful study of crushing and concentrating methods, so as to minimize waste and loss. In most cases, the actual treatment falls far short of this, and possibly half the molybdenite in the ore is lost. The producers of the concentrates are being paid high prices for their material, but the market is limited and dull. If molybdenite were sold cheaper, there is little doubt that ferro-molybdenum, 50 to 85 per cent molybdenum, could be sold at half its present price, and the uses of molybdenum in steel correspondingly increased. New uses have also been found, such as the molybdenum wire so useful in electric resistance furnaces. This wire is scientifically very useful in that it resists the alloying action of many liquid metals even at very high temperatures. Dr. C. G. Fink of the Edison Lamp Works has studied these notable physical and chemical properties, and has described them in the *Transactions* of the American Electrochemical Society (vol. xvii., page 229, 1910).

ZIRCONIUM.

We may mention this element, which, as metal, is rare enough, but whose oxide has recently been found in considerable abundance. The familiar mineral zircon is the silicate, containing nearly 50 per cent of zirconium, but it is found only in limited amount. In the last ten years the oxide, baddelyite, has been found in large quantities in Minas Geraes, Brazil, running 75 to 95 per cent pure, giving 50 to 75 per cent of the metal. This source is now so common that it sells at 4 to 5 cents per pound, and is being used in large quantities as a refractory material, on account of its high melting point (2,000 deg. Cent.), high resistance to all kinds of slags, low thermal conductivity and low coefficient of expansion.

The metal, however, is almost an unknown quantity. It has been obtained by the action of potassium or sodium on the anhydrous fluorides. Fused, it is white, density 6.4, melting point 1,500 deg. Cent., hard enough to scratch quartz. Ferro-zirconium has been made in the electric furnace and used in small amounts in steel with rather indefinite results. And yet, if some very useful proportions of zirconium were discovered, the metal could undoubtedly be prepared at a reasonable price—only a fraction of the $5 per ounce now asked for it as a chemical curiosity.

CERIUM.

There is a peculiar interest attaching to this metal and its close associates, from the fact that hundreds of tons of fairly rich cerium material is lying on the waste heaps outside of the incandescent mantle factories. The thorium ore used by these factories is monazite—a phosphate of the cerium earths plus thorium silicate. On extracting the thoria, the residue is worthless for mantle fabrication. It is known as "commercial cerium carbonate," and contains cerium, lanthanum, neodymium, praesodymium, samarium, gadolinium, yttrium, ytterbium, a little thorium, and considerable alkalies, iron, phosphoric acid and silica. By treatment with acids, precipitation of the rare earths, and ignition, a chocolate-brown mixture of oxides of the rare earth is obtained, in which cerium oxide predominates, and which contains nearly 50 per cent of metallic cerium. When this mixture is reduced directly, without further separation, to the metallic state, an alloy of the rare earth metals is obtained which is known as mixed metal (mischmetal) or impure or commercial cerium. The composition of mischmetal naturally varies, but may be taken as approximately 30 to 50 per cent of cerium, 15 to 25 per cent of lanthanum, 10 to 15 per cent of the didymiums, up to 20 per cent of the yttrium metals, and 1 to 5 per cent of thorium.

An immense amount of laboratory and practical work has been expended on the production of mixed metal and of purer cerium. Prof. Muthmann and his students in Munich and Alcan Hirsch in the United States deserve particular mention for their articles, in *Liebig's Annalen* (1902 to 1910) and *Transactions* American Electrochemical Society (1911) 20, pp. 1-102, respectively. Dr. Auer von Welsbach was the pioneer in the commercial manufacture and use of mischmetal. Annoyed by the sight of heaps of the cerium residues around his mantle factories, he experimented with their reduction to mischmetal and with the possible uses of the latter. Finding that it gave off sparks when scratched he conceived the idea of using it in automatic lighters, but found that it sparked far too feebly and unreliably to be practical. He then thought that if he purified the cerium it might give sparks more freely, but on making the purest cerium he found it to spark less than the impure metal. Turning in the opposite direction, he took mischmetal and added to it alloying metals not of the rare earth class, and found that they increased the sparking property. Iron, for instance, when increased to 30 per cent gave an alloy with remarkable spark-giving properties, such as make it most efficient and reliable in automatic lighters. This has formed the basis of the "pyrophoric alloy" industry, since although other metals have similar effects the 30 per cent iron alloy is probably the best sparking alloy, for general use, so far made.

The electrolysis of fused cerium salts, double chlorides or double fluorides, to give the melted mixed metal is carried on on a large scale in Austria at Trebach, in Germany near Berlin, and was commenced in the United States, in 1916, near New York City, by Mr. Hirsch and his associates. The technique is not easy to master, and all the works keep their operations as secret as possible. The principal difficulties are the re-solution of deposited metal, metal fog, and scattering of the metal as fine globules or "metal-mush" through the electrolyte, making it difficult to unite the metal to one melted mass. Since the latter trouble is largely due to surface tension, a study of this property, particularly how it can be diminished, might help in overcoming the difficulty. As an example of the opposite effect, the cupeling of lead on a bone-ash muffle depends absolutely, for its success, on the surface tension of the molten lead. But, metallic tellurium, in quite small percentage, *decreases* the surface tension of the lead so greatly that the metal *wets* the cupel and cupelation is rendered impossible. Arsenic, on the other hand, *increases* the surface tension of melted lead, and is therefore purposely added to it, about 0.25 per cent of it, to lead being made into lead shot, in order to make rounder shot.

A physical investigation of such effects on cerium might well assist in overcoming the scattering of the metal in globules in the electrolyte. Another direction in which improvement might be made would be the careful study of the eutectics of mixtures of cerium salts with barium salts, so as to find an electrolyte of lower melting point in which the losses by re-solution of deposited metal would be less than they are at present. Another possible improvement would be the finding of an electrolyte which would dissolve cerium oxide or the mixed oxides directly, and give metal by electrolysis. Such a bath has been discovered for aluminium oxide, and a long experimental search for a similar bath for the cerium oxides would be amply justified.

The possibility of using the 30 per cent iron alloy as a melted cathode, and enriching it in cerium by electrolysis, might be considered. If we had the fusing point curve of cerium-iron alloys we could draw some useful conclusions in this direction. The addition of small amounts of other metals to the bath, so as to produce other useful cerium alloys directly, might facilitate the electrolytic operation. Furthermore, experience with the process, particularly by those familiar with the electrolysis of molten baths for sodium, magnesium or aluminium, will very probably lead to considerable improvements and reductions of cost.

The uses of cerium and particularly of its alloys are sure to increase, and may attain considerable proportions. It has been proposed by Borchers as an addition in small quantity to aluminium, to improve its properties. But the large use will always be the pyrophoric alloys, which have so largely replaced matche Before the European war, over 3,000 workers were en ployed in Austria in this industry of pyrophoric alloy and automatic lighters. Mistakes were made in tl early days of the industry, and some alloys put in lighters which crumbled to pieces by the time the a paratus reached Australia, but continual improveme was being made, until a satisfactory substitute f matches was attained. The improvement most neede in the pocket lighting apparatus is to be able to di pense with alcohol or similar liquid; a wick impre nated with a *solid* combustible which can be ignite by a pyrophoric alloy, would give a great impetus t this art.

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