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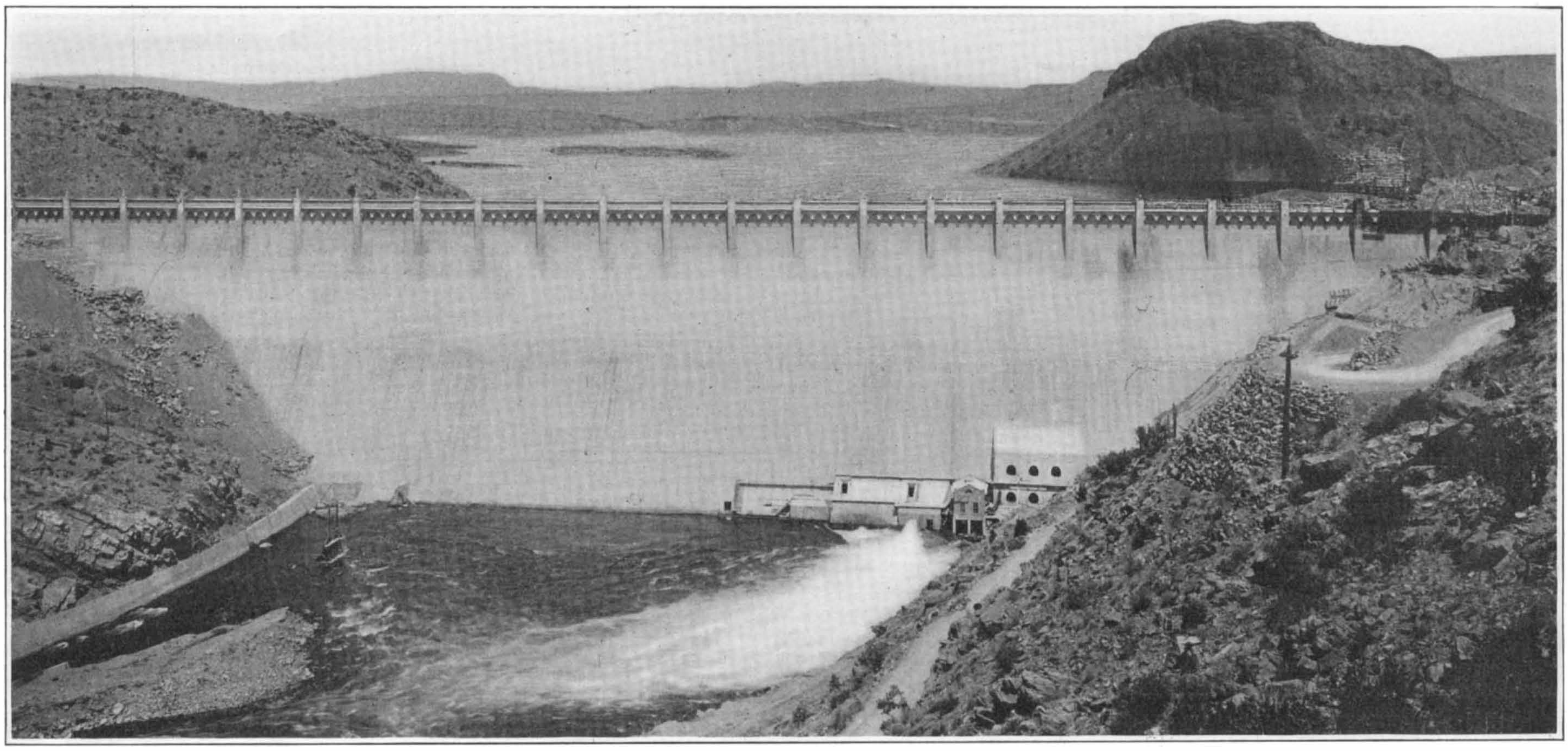


The Elephant Butte Dam viewed from down the stream. It is 1,310 feet long and 205 feet high.

View across the dam on its downstream face. This dam provides water for irrigating 200,000 acres of land in the Rio Grande Valley, in New Mexico and Texas.

THE ELEPHANT BUTTE IRRIGATION DAM.—[See page 37.]

The Specific Characteristics of Vitality*

Essential Differences Between the Living and Non-Living State

By Prof. David Fraser Harris, M.D., D.Sc., F.R.S.E.

THE attempts to identify life with "mechanism" depend chiefly on certain analogies between living beings and man-made machines or engines of some sort.

In a certain sense living beings are mechanisms, as when we choose to regard the body as a means of transmuting the chemical energy of food into the kinetic forms of heat and movement: here we may speak of the body as a heat engine. But to insist on describing a warm-blooded animal as a heat-engine is to concentrate our attention on one phase of its activity and totally to overlook a number of aspects in which it does not at all resemble a man-made machine.

Certain tissues of the living body are so disposed that they perform the functions of valves, levers, pulleys, hinges, all of which contrivances act precisely as metal valves, levers, pulleys, or hinges; but to admit this is not by any means to see no essential difference, physico-chemically, between protoplasm and machines of purely human construction. To say that there is no essential difference between the growth of a crystal and of an infant is to magnify the resemblances out of all proportion to the differences. But this sort of thing is what Prof. Ostwald does when he writes[1], "Our observations so far have shown the organisms to be extremely specialized individual instances of physico-chemical *machines*."

He has been comparing a living organism to a flow of water through a pipe; and, by laying great stress on the truth that each is not a stable but a stationary form of matter, that is, the form although not the matter of the jet and of the body respectively is conserved from moment to moment, Prof. Ostwald finally loses sight of any fundamental differences between the non-living and the living forms.

That living matter is able to transform energy and is itself highly unstable, chemically speaking, need not compel us to regard it as precisely in the same category as certain other much more stable forms of matter which also are able to transform energy.

The following enumeration of the properties of protoplasm or living matter would probably be disputed by no philosophical biologist as constituting the characteristics of the highest (mammalian) type of protoplasm.

1. The possession of affectability (irritability);
2. The possession of functional inertia;
3. The power of transmuting the chemical energy of food into the kinetic forms of heat, movement, nerve energy, electric current, and sound.
4. The power of assimilating matter which is chemically unlike the living substance, and of growing thereby.
5. The power of producing, under the influence of foreign substances or poisons, anti-bodies (anti-toxins, or ferments) designed to render the former innocuous.
6. The power of reproduction, that is, to cast off an organism capable of independent existence which shall perpetuate the parental type.
7. The power or propensity to evolve, from a relatively simple microscopic layer of cells, all the highly differentiated tissues and systems of the adult body.

Now it is undeniable that some of these characteristics of livingness are also possessed by matter which is not living and has never lived. For instance, affectability or irritability, found in every text-book of physiology as a property of living matter, is certainly a property of such lifeless matter as gun-powder or dynamite and of many another unstable chemical substance. Gunpowder has affectability toward the stimulus of a spark, and dynamite has affectability toward the stimulus of concussion, for affectability is but the power of responding to a stimulus.

Similarly functional inertia—or the power of non-response to a stimulus—is a property possessed both by living and by non-living matter. In living matter it is the property by which limits are set to its activity, by which it is made insusceptible to certain stimulations, by which rates of response beyond a certain number are made impossible; it is that property which prevents indefinitely long-continued action and unending response.

But clearly this same property is possessed by certain chemical systems. Thus dynamite has inertia toward a spark; it explodes by concussion, not by ignition.

The extreme molecular instability of certain substances, the picrates, fulminate of mercury or of silver, may certainly be called their affectability toward stimuli tending to cause their disruption, but their possession of this high affectability does not entitle these materials to be called living.

Affectability is a property not of living matter exclusively, but of many varieties of non-living matter as well: affectability is correctly classified as one of the fundamental properties of protoplasm, but protoplasm is not living matter because it possesses affectability. Living matter also possesses functional inertia, which is the power to disregard or be oblivious to certain kinds of stimuli; but some kinds of matter that are non-living also possess this property in a high degree. The possession, therefore, of a degree of inertness toward certain forms of stimulation does not distinguish living from non-living substance. Both affectability and functional inertia are vital properties, but they are properties not possessed exclusively by living matter.

When we pass on to the other characteristics of vitality, we find ourselves on very different ground.

Living animal bioplasm has the power of growing, that is, of assimilating matter in most cases chemically quite unlike that of its own constitution. Now this is a remarkable power, not in the least degree shared by non-living matter. Its very familiarity has blinded us to its uniqueness as a chemical phenomenon. The mere fact that a man eating beef, bird, fish, lobster, sugar, fat and innumerable other things can transform these into human bioplasm, something chemically very different even from that of them which most resembles human tissue, is one of the most extraordinary facts in animal physiology. A crystal growing in a solution is not only not analogous to this process, it is in the sharpest possible contrast with it. The crystal grows only in the sense that it increases in bulk by accretions to its exterior, and only does that by being immersed in a solution of the same material as its own substance. It takes up to itself only material which is already similar to itself; this is not assimilation, it is merely incorporation.

Writers of a materialistic bias have, however, striven to regard such growth of crystals as not essentially differing from protoplasmic growth. Except that matter is taken up from outside in both cases, there is no similarity between the two processes at all. Growth of bioplasm, which includes and is the outcome of the incorporation of the dissimilar, the essence of the metabolic phenomena characteristic of living matter, is something *sui generis*.

The term "growth," strictly speaking, can be applied only to metabolism in the immature or convalescent organism. The healthy adult is not "growing" in this sense; when of constant weight he is adding neither to his stature nor his girth, and yet he is assimilating as truly as ever he did. Put more technically: in the adult of stationary weight, anabolism is quantitatively equal to katabolism, whereas in the truly growing organism anabolism is prevailing over katabolism, and reversely in the wasting of an organism or in senile decay, katabolism is prevailing over anabolism. The crystal in its solution offers no analogies with the adult or the senile states—but these are of the very essence of the life of an organism. The crystal, when not incorporating molecules exactly similar to itself, is not in any sense active; but an organism at all stages of its life-history is active—unless indeed it is in the state of latent life.

The fact, of course, familiar to every beginner in biology is that the crystal is only incorporating and not excreting anything, whereas the living matter is always excreting as well as assimilating. This one-sided metabolism—if it can be dignified with that term—is indeed characteristic of the crystal, but it is at no time characteristic of the living organism. The organism, whether truly growing or only in metabolic equilibrium, is constantly taking up material to replace effete material, is replenishing because it has previously displenished itself or cast off material. The resemblance between a so-called "growing" crystal and a growing organism is verily of the most superficial kind.

It is true that a living organism resembles a wave—the form persisting, the matter changing—but that does not entitle us to lose sight of the inherent differences between the two; it justifies us neither in calling the wave alive nor the living organism "mechanical." Assimilation of matter is, then, a vital characteristic, specific for livingness in a sense in which neither affectability nor functional inertia is specific for it.

But when we pass on to that vital property, the power to produce anti-bodies, we encounter a property whose specificity is absolute. This is a property known only within the last few years; and as it is the basis of immunity from the poisonings due to disease-producing micro-organisms, it is being very carefully studied at the present time by workers in pathological chemistry.

Hardly any subject of biochemistry is so unsuited to popular presentation, but the principle of it may be stated as follows; if material foreign to the blood or tissues of an animal be introduced into that animal's blood, then the body cells proceed to elaborate a substance (anti-body) designed to counteract or neutralize the foreign substance introduced.

The substance introduced is known as an antigen; the substance produced as a vital response to the foreign stuff is the anti-body. This is evidently a protective chemical procedure, or "mechanism," as it is called for short; it is the expression of the body's power of combating chemical insults by chemical means. As a chemical process it is highly specific, that is to say, the particular anti-body which neutralizes the poison of diphtheria, for instance, will not also antagonize the poison of typhoid fever or of pneumonia. Each toxin is responded to only by its own specific antitoxin. Now this is wholly without parallel or analogy in the world of the non-living. *It is characteristic of life alone*, it is specific. Modern biochemistry has, then, given us a new feature or differentia of living matter, a power of protoplasm not recognized a few years ago, not known to the men who regarded affectability as the chief vital manifestation.

The properties of reproduction and differentiation of tissues, though recognized for a much longer time than the formation of anti-bodies, are none the less confined to life alone. Non-living matter behaves in no wise which could be construed into regarding it as capable of reproduction or of progressive morphological differentiation.

Homogeneous non-living matter makes no spontaneous efforts from within toward heterogeneity.

If anyone cares to regard the breaking off of a portion of a crystal as analogous to the giving birth to an immature organism, capable, in due time, of an independent existence, he may do so as a poetical exercise, but not as any contribution to the philosophy of biology.

The power of sexual reproduction is entirely *sui generis*, and has no analogy in the non-living world. The so-called similarities between sexual phenomena and the attraction of oppositely electrified atoms or ions are really only pretty fancies. Possibly the most mysterious or wonder-rousing property of living matter is its inherent power of progressive cell-differentiation.

Out of the single fertilized ovum (or egg), usually of microscopic size, there arises in due time the perfect animal; the simple ovum having given place to millions of cells, each having its own niche in the living mosaic. And the end-product of the cell evolution is highly characteristic, for the microscopist can tell at a glance a brain-cell from a liver-cell, a bone-cell from a cell of the retina, and so on. Morphological differentiation evidently underlies functional specialization.

Sometimes these self-developing systems are spoken of as "mechanisms," but that is justified only in the interests of brevity of expression: no man-made mechanism ever evolved itself, or, being made, ever became anything else; but this is precisely what the "mechanisms" of protoplasm are continually doing. The single and simple can evolve into the multiform and complicated merely, apparently, by possessing the power of assimilation. The like can evolve into the unlike; the cells of the embryo which at one stage are practically all alike are destined to become something exceedingly different, as different as brain from bone. A mere mass of spherules will shortly become all the complexities of the eye or ear; some lens-cells detached from the lens of the eye can produce a lens outside of and away from the eye altogether; some bone-cells placed on the skin forthwith proceed to develop bone on the outside of the body.

It is customary to make a great deal out of radium being able to disintegrate and become something else as though this interesting transformation could blur the sharp lines of distinction between the living and the non-living.

It is characteristic of vitality to have its youth, its prime, and its decline, but there is nothing of this in the non-living. The hills are everlasting; but neither the sheep nor the shepherds are. "Change and decay" applies only to the living environment: the "birth" and "death" of worlds is poetry.

It is of the essence of living things to have phases or rhythms in their metabolism and phases or stages in their life-history. If the non-living corresponds at all to any phase or stage of the living matter, it is to the phase of latent life.

Latent life is that condition of living matter where there are no signs of life, only the potentialities of life

*Science Progress.

[1] Ostwald, "Natural Philosophy," London: William & Norgate, 1911.

in the future. The vital material of the frozen frog, insect, fish, or rotifer, while it remains in latent life, is in the *status quo ante* just as a stone is; but whereas the frozen organism can revive, as we say, or again shows signs of vitality, that is, come out of its latent phase, the stone or crystal cannot, and all attempts to represent it doing so are based on metaphors.

The living thing tends to death; the non-living tends to nothing at all. Death is the natural end of life; physical science as such knows nothing of the endless existence of living things.

In life there is some affectability and some functional inertia; in latent life there is minimal affectability and much functional inertia; in death there is no affectability and maximal functional inertia.

This is, then, a new definition of death, for it is a positive one, all others, such as "death is the cessation of existence," are negative. Whereas in life there are signs and potentialities for future life; in latent life there are no signs but only potentialities; in death there are no signs and no potentialities. This is another new positive definition of death.

These conclusions do not necessarily preclude the belief that living matter has been evolved from non-living as Sir Edward Schäfer and Prof. B. Moore indicate. Possessing the fundamental properties of affectability, functional inertia, and the power to transmute energy, it is conceivable that non-living matter became, physico-chemically, so unstable that it finally acquired the four properties which have just been described as specifically characteristic of it: when it had acquired these it was alive.

Functional endowment, therefore, and not the possession of any "vital force," constitutes livingness. The desire of the chemists to create living out of non-living matter is not hereby ridiculed, neither is it pronounced impossible. But we must be prepared beforehand to recognize this man-made living matter whenever and wherever we may be privileged to see it. Presumably it will be first presented to us in a test-tube. How shall we know that it lives? The biochemist says that protoplasm is an irreversible colloidal hydrosol of emulsoid constitution: excellent, but how may we know that this hydrosol is alive? Not from its conforming to the above description, for matter entirely dead might still be so described. By its "extreme complexity"? No; for again extreme chemical complexity can characterize both non-living and dead matter. By its possessing affectability, functional inertia, and the power of transmuting energy? Once more, no, for all these three are possessed by certain lifeless substances. Matter, whatever its origin, cannot be pronounced alive unless it is capable of assimilating the unlike, of producing anti-bodies, of reproducing itself and of undergoing spontaneously a certain degree of morphological differentiation.

These are the credentials of living matter as we find it in the universe to-day; matter, wherever it has arisen, which possesses these four properties must be called alive.

Some years ago I contended[2] that affectability and functional inertia were *the two fundamental* properties of living matter, and such indeed we must regard them. No kind of matter which does not respond to a stimulus can be called alive; all matter which is alive can or may respond to a stimulus, but affectability is shared by non-living matter. Conversely, matter which was the ever-lasting plaything of stimulation, which could not resist or be oblivious to certain stimuli at certain times, would not be alive. It is of the essence of livingness to disregard some stimuli, to prevent some responses, to set limits to activity, to act rhythmically and not constantly or continually; but insusceptibility to stimulus is a property shared also by non-living matter.

It is theoretically possible that both these fundamental properties of living matter came to be found in it because they were inherent in the pre-existing non-living matter from which the living may be supposed to have been evolved. Similarly for the power of transmuting energy, a property notoriously not confined to livingness.

Nor does anything said here contradict the belief that affectability, functional inertia, and the transmutation of energy are primary or fundamental properties, while the last four are secondary or derived. For instance, if living matter had no affectability, it would be unaffected by the presence of food material, and so would not respond to it in the direction of assimilating it.

Recent physiological work has made us aware of a power in living tissues to offer resistance to the so-called "physical forces." We have been shown that the important function of absorption of food from the intestine is not capable of being explained by the laws of "physical" osmosis alone. The "mechanism" of absorption is not mechanical in the sense that it is the outcome of laws operative entirely in non-living matter. Prof. Waymouth Reid has demonstrated that if the living cells lining the alimentary canal be removed, the food is absorbed less perfectly than before, although now it is of course actually nearer to the blood which is ultimately to receive it. Similarly, Prof. Gregor Brodie has proved that in the kidney, merely physical forces, blood-pressure, etc., will not account for the formation of the watery secretion of that gland; he is compelled to speak even of the water as being vitally secreted. Dr. J. S. Haldane, of Oxford, asserts that under certain conditions the living lining of the lung acts, as regards the excretion of carbonic acid gas and the intake of oxygen, in direct opposition to purely physical diffusion.

I have purposely not grounded the thesis of this paper on the phenomena of consciousness. The existence of consciousness *is* the supreme distinguishing feature between the living and the non-living; but our uncertainty as to the existence of self-consciousness in the lower forms of life precludes us from making dogmatic statements about its significance as a differentia of livingness in every one of the types of living matter. It seems safe to assume that consciousness does not arise until the related neuroplasm has attained to a certain degree of functional differentiation.

Certain biologists, for instance Haeckel, have *on the contrary*, assumed that consciousness does exist in every animal form from amœba to man; but as this position is absolutely beyond the reach of proof, it cannot be used as a datum for further argument.

The assumption seems extremely improbable; were it true, the *fœtus in utero*, for instance, would be a self-conscious existence; but if we are sure of anything, we are sure that it is not. If we could be certain that consciousness is an accompaniment of all living matter, then we could regard it as an additional differentia of protoplasm, for no one holds, save as poetry, that non-living matter is conscious.

In those animals which possess it, consciousness is a characteristic of life *sui generis*, in which respect it resembles the power of producing anti-bodies; but only somewhat highly differentiated protoplasm possesses either of these properties.

Enough has been said to justify us in refusing to see no essential differences between matter in the living and in the non-living state. That living matter had its origin in the non-living is a conceivable evolutionary possibility; but that we may discover in matter which has never lived all the properties whereby we recognize vitality does not seem a correct interpretation of the world of life as we find it.

By magnifying resemblances and by explanations based on analogies, we can endow the non-living with the semblance of life, but we are somehow certain after all that differences are there, and that it is poetry and not science that has been enriched. Between the living and the non-living there is a great gulf fixed, and no efforts of ours, however heroic, have as yet bridged it over.

[2] Fraser Harris, "The Functional Interia of Living Matter." London: Churchill, 1908.

The Microscope Fine Adjustment

In the choice of a microscope, the amateur too often neglects to ascertain the efficiency of the fine adjustment when working with really high powers. In some medical schools, where the matter is entrusted to the lecturer, the same holds good, and microscopes of an old and once excellent pattern are still recommended, though entirely out of date and utterly unsuitable.

Two years ago Prof. Minot, of Harvard, called upon me, and together we discussed a few points about the modern microscope. "Do you know the ——— microscopes?" he asked. I told him I did. "And what do you think of them?" he said. I answered, "Excellent, except that the fine adjustment is not good enough for oil-immersions." "You are quite right," he said. "I told them so only a few months ago, and they are altering their pattern." And altered these microscopes are, though even yet not quite perfect, in my own opinion.

The first point to test is whether there is any backlash or loss of time in the movement. As a matter of fact, this is seldom found, as most microscope makers obviate all chance of this by means of a counter spring, which in most cases acts admirably. Only in old and second-hand instruments is this defect sometimes to be detected, and a new spring soon puts it right. Any side movement can also usually be corrected by tightening the screws of the slide, or in some cases by a drop or two of good sperm oil or oil of sweet almonds on the movement, wiping off all superfluous oil with a clean linen cloth. Usually it is only apparent with the highest powers. But it should not exist at all, and indicates soft metal or great age, or both.

Roughly speaking, fine adjustments fall into two classes—those acting directly with a screw and those having in addition a lever or cam, or some intermediate method of diminishing the motion of the screw.

In the first class the threads of the screw are almost invariably half a millimeter (one-fiftieth of an inch) in pitch. Thus one whole revolution of the screw gives a movement of half a millimeter. This acts very well for all objectives up to four millimeters (one-sixth inch) in focus, and up to about .65 in angular aperture. Such a lens, with the highest eye-piece in common use, gives a magnification of about 600. Most observers will not use it for a magnification of more than 400, but the image is hardly impaired even at the higher figure. Such an objective will work through any thickness of cover within reason, and needs neither collar correction nor any alteration in length of the draw tube for varying thickness of covers.

When, however, we substitute an objective of the same focal length, but with an aperture of .85, we find that this make of fine adjustment breaks down, and is scarcely sensitive enough. One maker at least obviates this difficulty by making his screw one-third of a millimeter in pitch; but even then it breaks down with objectives of three millimeters and still more with a 2.5 millimeter, the highest dry-power objective in common use for bacteriology. For oil-immersions of the usual power and aperture, and still more for microphotography, this form of fine adjustment is utterly out of question.

So far we have spoken only of what experience teaches. It remains for us to deduce conclusions and state results, and apply them to higher powers.

Prof. Abbe long ago demonstrated that the depth of focus (or depth of sharpness or penetration) was in inverse proportion to the product of the numerical aperture and the initial magnification of the objective.

Thus the depth of focus of the four-millimeter objective of N. A. .65 would be

$$\frac{1}{.65+40}$$

the latter being the initial magnification of the system with the one-hundred-and-sixty-millimeter tube.

Now let us proceed to the ordinary one-twelfth-inch oil-immersion of N.A. 1.30, which is most commonly used, and costs everywhere £5. It is in reality a one-fourteenth-inch, i. e., 1.8 millimeter objective, and hence its initial magnification is $\frac{160}{1.8}$, say ninety. Thus its depth of focus is $\frac{1}{1.30+90}$

$$.65\times 40 = 26.$$
$$1.30\times 90 = 117.$$
$$117 \text{ is to } 26 \text{ as } 4\tfrac{1}{2}\times 1$$

In order, therefore, to be perfectly efficient the fine adjustment for the 1.8 millimeter lens should be four and a half times as slow as one for the four-millimeter objective. In order to embrace oil-immersions of N. A. 1.4, we may change 4½ into 5 with advantage.

The four-millimeter objective requires a movement of .5 millimeter per turn of the fine adjustment; the 1.8 millimetre would therefore require $\frac{.5}{5} = .1$ millimeter per turn.

It is objected that such a slow movement (one-two-hundred-and-fiftieth inch) is not a convenient one with medium powers, as it is difficult to decide which is the best focus. This difficulty, however, completely disappears with experience. The tyro may try the dodge of putting the image just out of focus; then turn the fine adjustment until it is equally out of focus the other way. Then turn the milled head just half the distance back, and the correct place will be found.

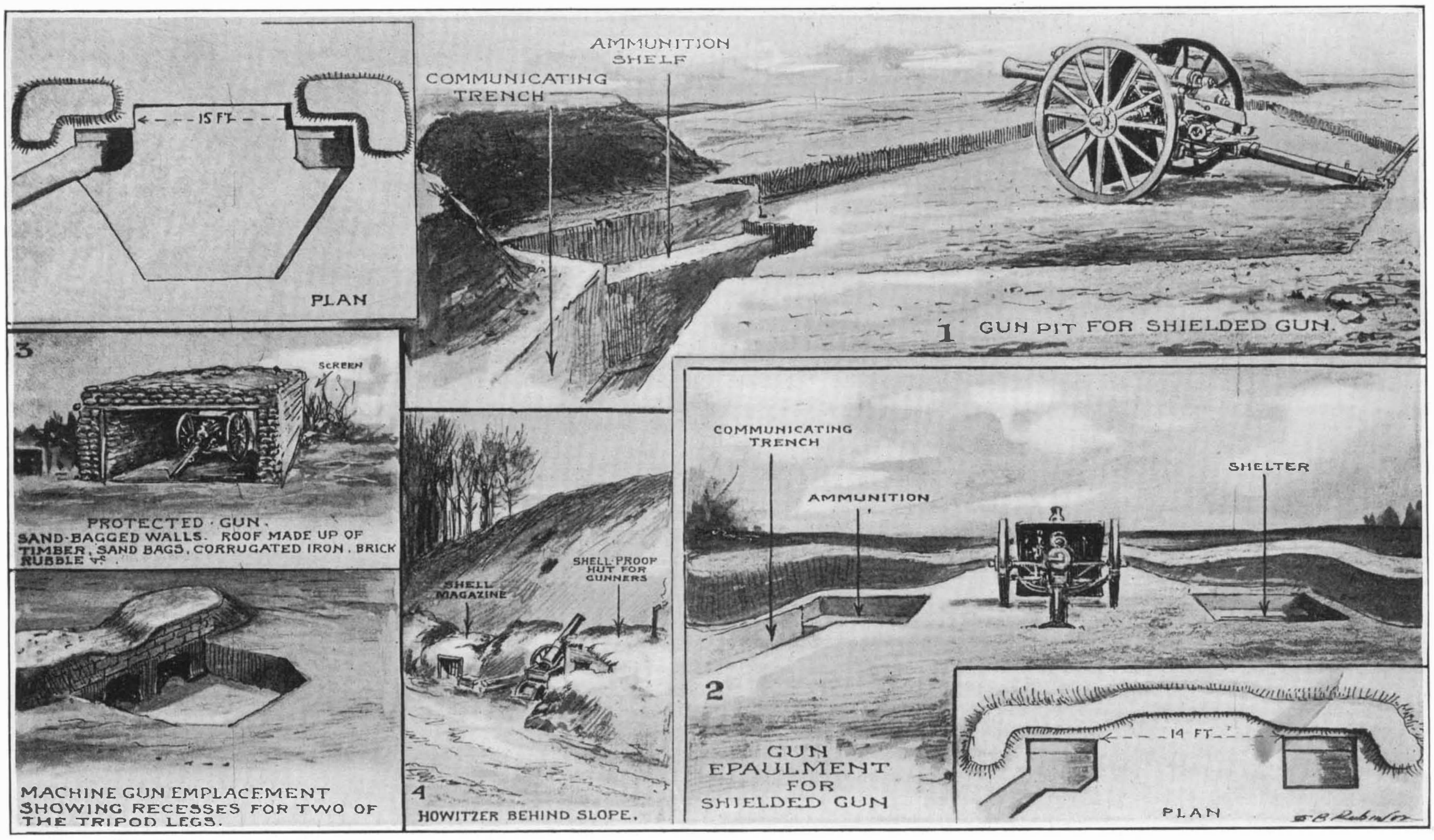
One maker gets over the difficulty in a very ingenious and efficient manner. A screw with a coarse thread works *inside* another with a thread five times as fine. The coarse thread moves the body about one-sixtieth inch per turn; the fine one, one-three-hundredth inch. We should have preferred one-half millimeter (one-fiftieth inch) and .1 millimeter (one-two-hundred-and-fiftieth inch), but this is perhaps hypercritical. At any rate, the idea is a good one, and gives excellent results in practice. It shows also how well theory and practice agree.—E. Ardron Hutton, M.A., in *Knowledge.*

Prehistoric Irrigation Ditch Built by Indians

There exist in several parts of Arizona the remains of irrigation systems that date back to prehistoric days, when some quite highly civilized Indian tribes inhabited these valleys.

One of the most famous of these ancient irrigation works is on the Arizona state highway from Prescott to the Grand Canyon. Water was taken from what is known as Montezuma's Well, a curious natural well 440 feet in diameter and 93 feet deep, except in one spot, where no bottom was reached at 500 feet.

The water carries a great deal of lime in solution, and the sides of the ditch have been preserved by the petrifaction of the original earth. One rancher at the present time is using several thousand feet of the old ditches, after merely cleaning them out. F. R. Goodman, State highway division engineer, was once tempted by curiosity to run a line of levels along the bottom of one of these old Indian ditches. He found the grade to be almost perfectly uniform at a rate of 0.01 foot per 100 feet.—*Engineering News.*



From The Illustrated War News.

Gun Emplacements and Concealment*

Considerations That Determine the Selection of Battery Positions

WHILE success in artillery operations is, as it always has been, dependent on the efficient concealment of the battery in action, the advent of the aeroplane as a scout has made such concealment a more difficult matter. Consequently, gun-positions which in the past would have been perfectly satisfactory are to-day comparatively useless. In order to meet this difficulty, it is usual to paint guns and limbers with splashes of various colors, so as to make them blend as far as possible with the surrounding landscape.

In selecting a position for a battery it must be remembered that an object is clearly seen on the sky-line which would be practically invisible if situated on the face of an incline in full view of the observer but with a background of earth instead of sky. It is, therefore, advisable to select a battery position on the face of a slope (*A*—Fig. 5) rather than one just behind the ridge (*B*—Fig. 5), as the latter would involve a sky-line background for guns other than howitzers (Fig. 4), and for the observers in any case.

If the gun-position is such that it may be necessary to retire the guns from time to time during daylight, a position behind the ridge is a better one than that on the face of the slope, as such an operation would in the latter case involve exposure on the crest during transit. A screen erected behind a field-gun is often more effective than one placed in front, as the latter must be low enough for the weapon to fire over it, while the former can be of any desired height, and gives good concealment from the enemy's position if its color blends with that of the gun, etc. Field-guns operating on open ground may be concealed in "gun-pits" or by "epaulements" (Fig. 3). In the former, a pit is excavated, the floor of which slopes downward in the direction of fire to a depth of about 1½ feet, a bank of earth about 3 feet high being erected in front of the position to the right and left, with the line of fire passing between them (Fig. 1).

A communication-trench enables the gun-crew to bring up ammunition, etc., without exposing themselves. When the field-work known as an epaulement is used, the gun stands on the surface of the ground, and a bank of earth is extended across the front of the position, this bank being about 1 foot high in its center—over which the line of fire passes—and 3½ feet high at each end. The same arrangement of communication-trench is adopted as in the case of the gun-pit.

The decision as to whether a gun-pit or an epaulement is preferable depends, of course, on local conditions. A gun-pit is constructed in less time than an epaulement, as less earth is required to form its embankment, the bulk of this earth being taken from the pit which accommodates the gun. The epaulement (Fig. 2) is generally worth the extra time that it requires to construct when sufficient time is available. In this case the gun stands on an undisturbed and consequently firm surface, while its discharge is not so liable to raise dust and so betray its position.

Dry earth in the immediate vicinity of a gun is always well watered to keep down the dust, or, when water is not available, covered with hides or gun-sheets. When any excavations have to be made, disturbed surfaces should be covered with turf, branches, or other natural substances, so as to make them blend with their surroundings, and in that way avoid attracting attention.

A comparatively permanent fortification is formed by a system of deep gun-pits with earth-covered roofs linked together by underground passages in which are situated isolated magazines containing reserve ammunition, these magazines being so far apart that the explosion of one of them is not likely to endanger the others. A subterranean tramway sometimes connects the fortification with the ordnance depôt and serves to keep up the supply of ammunition, stores, food, etc. This class of gun-pit, it should be noted, is suitable for howitzers only, the high-angle fire of the howitzer permitting it to be placed well below the parapet of the pit. As will be seen, the location of the artillery in action is a matter of only secondary importance to the caliber and reliability of the guns themselves.

Fig. 5.—Gun-emplacements on a hill-face (A) and behind the crest-ridge (B).

*The Illustrated War News.

Suffocating Gases and Their Antidotes

AN Italian chemist named Guareschi recently gave an address before the Chemico-Technical Society in Turin on the subject of the gases which have a choking or suffocating effect and those which affect the tear-glands. This address was reported in a French magazine, from which the following abstract, appearing in the German sicentific weekly, *Prometheus*, is taken:

The suffocating gases and fumes most suitable for military purposes comprise chlorine, hydrochloric acid gas, bromine, hydrobromic acid gas, nitrogen dioxide, nitrosyl chloride, phosgen, hydrocyanic acid gas, cyanogen chloride, cyanogen bromide, ammonia, sulphuretted hydrogen, sulphur dioxide, phosphine, and arsine. Among these it is naturally only those which are furnished in larger amounts and at reasonably low prices by chemical industries which are mainly advisable as first choice. This is true, for example, of chlorine, which is manufactured in large quantities even in times of peace, and of bromine, which is likewise to be had cheaply (from the Salzburger salt deposits).

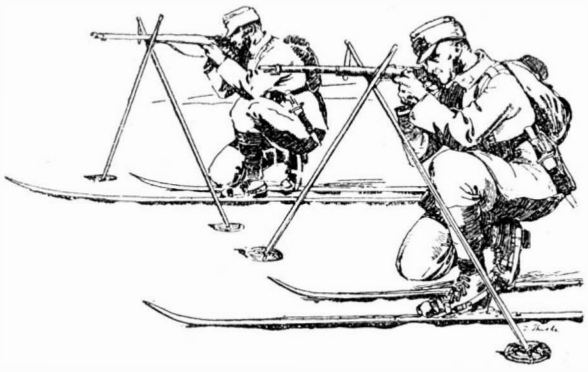
In the second rank come phosgen, nitrosyl chloride, and other products of chemical industries. Other prerequisites for military purposes are that the gases should be heavier than air, that they should retain their suffocating quality even when largely diluted with air, and that they should be readily transportable in the liquid form. It is desirable also that their solubility in water should be as small as possible, and that they should have but little capacity for being absorbed by other chemicals.

These last qualities are lacking in those gases which are both cheapest and most certainly effective. Hence it is possible for the enemy to neutralize the harmful effect by wearing face-masks containing cloths or sponges saturated with solutions of suitable antidotes.

Alkaline solutions (of soda, for instance,) are used to neutralize chlorine, bromine, hydrochloric acid, hydrobromic acid, nitrogen dioxide, sulphur dioxide, and other suffocating gases of an acid character. To neutralize chlorine and bromine it is also recommended to use solutions of sodium thiosulphate, either alone or mixed with solutions of soda. Weak acid solutions are a protection against ammonia fumes.

The best neutralizing substance for the most poisonous gases (chlorine, bromine, nitrogen dioxide hydrochloric acid, hydrobromic acid, sulphur dioxide, phosgen) is probably soda lime.

A variety of the dangerous gases now employed in warfare consists of those which cause the flow of tears. Guareselin mentions among these phosgen, nitrochloroform, chlorcarbonicacidethylether, benzyl chloride and benzyl bromide, thionyl chloride and fluoride, monochloraceton and dichloracetone, as well as similar organic substances whose fumes attack the eyes violently.



Balancing poles used as rifle rests.

Being towed by a horseman.

Operating machine guns on skis.

Campaigning in the Snow*

Some Things a Ski Is Good For

THE organized corps of ski-men of the German army have found during the past winter that aside from the facility lent to locomotion, the appurtenances of skiing are very handy things for various purposes. For example, the ski artist improves his marksmanship by thrusting his alpenstocks, of which he carries two, diagonally into the ground so that they cross at a proper height, and employing the crotch thus formed as a gun rest.

The members of a ski squad never have to sleep exposed to the elements. Each man plants his skis firmly in the ground so that they cross at a height of six feet or more; and by laying alpenstocks from crotch to crotch, and tying others across the middles of the sides by means of the foot-strap, a most admirable tent-frame is erected in a few minutes.

Wherever a ski-man can go there he can transport a small machine gun mounted on skis, as well as cans of ammunition, food, etc. If he should be so unfortunate as to be wounded, his companions will pack him back to the nearest base on a hastily improvised sledge built up on two skiis as runners. If he chances to be operating in connection with a force of cavalry, the ski-man does not even have to furnish his own motive power, but by means of lines attached to the saddle he catches on behind a mounted companion. That the "Schneeläufer" has frequent opportunity to hitch behind in this fashion is attested by the fact that he has coined a word to describe the act.

*From *Die Umschau.*

Skis used for tent frames.

Bringing in the wounded.

Paper Pulp From New Woods

ACCORDING to a publication recently issued by the Forest Service of the United States Deartment of Agriculture, satisfactory wood pulp for paper-making can be produced from a number of woods that have not hitherto attracted attention, and in proof of this statement seventy samples of paper are shown, manufactured by different pocesses, chiefly from woods hitherto practically unused for this purpose.

Tests showed eleven new woods that give promise of being suitable for the production of print paper while a number of others will produce manila paper and boxboards. In connection with this work valuable work has been done in developing new methods of manufacture and the improvement of the old methods, which have remained practically unchanged since they were introduced in 1867.

The Elephant Butte Dam

The Greatest Irrigation Storage Enterprise in the World

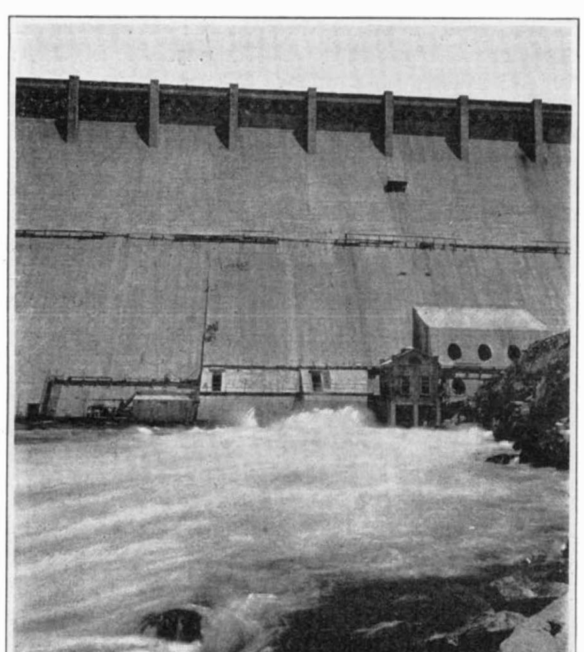
WITH the completion of the great Elephant Butte Dam, in Sierra County, New Mexico, one of the most extensive irrigation schemes in this country is nearing realization, and in due course some 200,000 acres of wonderfully fertile land in the states of New Mexico and Texas will become productive.

As is generally known, there are large areas of very fertile lands in the western and southwestern portions of the United States which have been practically valueless for lack of water, and for a number of years both the Government and private enterprises have been constructing storage reservoirs and systems of irrigating canals that will make hundreds of thousands of acres available for agricultural purposes. One of the largest of these projects is the one that centers on the storage reservoir at Elephant Butte, which was recently completed, and which will be officially dedicated in October. Not only is the body of water formed by this dam, which has been thrown across the course of the Rio Grande River, the greatest of its kind in America, but it is said to be the greatest in the world, being several times greater than that formed by the celebrated Assouan Dam across the Nile, in Egypt.

To give an idea of the immenseness of this enterprise it may be said that the lake created by this dam is 45 miles long and averages 1¾ miles in width with a shore of 200 miles. The greatest depth, near the dam, is 193 feet, and the average depth is 66 feet. The lake has a water surface area of 40,080 acres and its available capacity is 2,642,292 acre feet, or 862,200,000,000 gallons, which it is expected will insure a sufficient supply of water to the district served for two years, thus insuring against a possible entire failure of rain in any single year.

What these startling figures mean is difficult for most people to clearly conceive, but graphically speaking, the water impounded is sufficient to cover the State of Deleware to a depth of two feet.

A few technical particulars relating to this dam may here be given: Active construction work was started July, 1910, and the dam completed May 12th, 1916, at an approximate cost of $5,000,000. It is 1,310 feet long, and has a total height from its foundation of 306 feet, and above the original river level of 205 feet. It is 215 feet thick at the base and the width of the roadway on the top is 18 feet. The dam is of the gravity type, straight in plan, and is built of cyclopean concrete with up and down stream faces cast against forms. The masonry in the structure amounts to 608,000 cubic yards, and this is said to be the largest piece of masonry in the world.



The power house, and rapids caused by water flowing from the water wheels.

It is interesting to note that this immense project of the United States Reclamation Service is not a new idea, but actually a revival of an ancient irrigation system that was built and operated by the old Spanish settlers who inhabited this region some four hundred years ago, for in a number of places the remains of irrigating ditches can be traced, and traditions have it that this country in those old days bloomed with vineyards that rivaled the finest in France and Italy. With the completion of this great modern enterprise there is no reason why those old days of prosperity should not be repeated a thousand fold, for the region served by the Elephant Butte reservoir possesses a soil of unequaled fertility and a climate wonderfully adapted to an extremely wide range of agricultural pursuits, and is noted for its healthfulness. The only thing lacking to make it an agricultural paradise was water properly distributed, and this the new irrigating system provides for.

How Long Will Our Oil Supply Last

AT a recent meeting of the Society of Automobile Engineers Dr. W. F. Rittman made the following statement: "We burn, in the form of fuel to replace coal, about 25 per cent of the crude oil that comes from the ground. We use another 25 per cent in the form of gas oils to make gas, where coal could be used with equal ease in a by-product oven. We are selling kerosene for less than it costs without paying nature for it. We use 25 per cent of the crude in internal-combustion engines. If we could take the crude out at one-fourth the present rate, make it all into gasoline and use coal for fuels for the other purposes as it should be used, then the exhaustion of our oil would not be a question of twenty-five years; it would be a question of seventy-five years."

Solid Solutions*

Inter-Metallic Compounds, and Annealing and Properties of Metal

The fact that almost all the alloys, which owe their practical utility to their toughness or combination of strength and ductility, consist of one or more solid solutions, has received due attention, but has not yet found any adequate explanation. The brasses, most of the bronzes, copper-zinc-nickel alloys—formerly known as German silvers, now designated nickel-silvers—light aluminium alloys for motor vehicles our coins, etc., are regarded as solid solutions, and the hardening of steel is attributed to the formation and subsequent preservation of solid solutions, to which again the predominating characteristics of alloy steels are ascribed. One might expect pure gold to be harder than gold containing another metal in solution, or, in a certain sense, as impurity, just as pure gold or any pure substance has a higher melting point than the impure substance. But it has long been understood that these two phenomena are not parallel. To what circumstance solid solutions of metals owe their special properties, in particular their high hardness, is not understood, however. The problems came before the Faraday Society recently.

The particular papers which we wish to notice to-day in the first instance were by Mr. F. C. Thompson, M.Met., B.Sc., of Sheffield University, on "The Properties of Solid Solutions of Metals and of Inter-Metallic Compounds," and on the "Annealing of Metals." Mr. Thompson had made an important communication to the Iron and Steel Institute, and had already brought a very suggestive investigation of the elastic strength of metals before the Faraday Society a few years ago. On the present occasion he first pointed out that great hardness of alloys went together with high electric resistance and with high maximum stress and low elongation, and that these properties were also conferred on the metals or alloys by cold work. The remarkable parallelism between the properties of a metal in the *écroui* condition and in solid solution with another metal suggested that distortion of the crystalline matter was present in both cases. Metallic solutions were truly crystalline; cleavage slipping under stress, well-defined etching pits and twinning pointed to that conclusion. In the space-lattice of such a solution the lattices of the two or more constituents were generally regarded as interpenetrating. Mr. Thompson, however, thought that the question might be simplified by considering one lattice alone. When an element *B* was added to an element *A*, the *A* atoms in the space-lattice were progressively replaced by the isomorphous *B* atoms, and the lattice passed imperceptibly from that of one pure element to that of the other. This atomic replacement should react on the physical properties, and implied, according to Gossner, an attempt at the equalization of the atomic volumes in the components, in the sense that, if an *A* atom occupied a greater volume than a *B* atom, the replacement would result in an expansion of *B* and a contraction of *A* when they crystallized together. The resulting distortion would give rise to elastic strains, probably of a high order, throughout the whole mass, to which the increased hardness was to be ascribed. On that view the maximum hardness should be observed in binary alloys (gold with silver or copper), which formed an uninterrupted series of solutions, when 50 per cent of each constituent was present, and that was invariably found to be so. As long as there were present few B atoms of small atomic weight, they would undergo much change, and the A atoms little change. As the B atoms became more numerous, the change of atomic volume and the increase of hardness would become smaller and smaller; for completely isomorphous metals the hardness curve should hence be parabolic with a flat maximum at 50 per cent composition. Now Desch had pointed out (*Transactions*, Faraday Society, 1915, page 521) that the atomic volumes of metals which formed uninterrupted series of solid solutions were in all cases very close to each other, and the mean atomic volume would therefore undergo very little change from end to end. In developing a simple formula for these relations, Mr. Thompson suggested that the hardness of a metal was determined by its intrinsic pressure (Traube). Dr. Desch subsequently objected that he could not form any clear view of Traube's intrinsic pressure, which would, moreover, fit alloys which were not solid solutions; but Mr. Thompson replied that his results agreed with Traube's.

From the point of his hypothesis it was immaterial which of the two metals had the larger atomic volume; the solid solution of the two would in all cases be harder than either consituent. In this conclusion he differed from Roberts-Austen, who, on the strength of his first researches of 1888, on gold alloys, had maintained that metals which diminished the tenacity and extensibility of gold had higher atomic volumes than gold, while those which increased these properties had the same or lower atomic volumes. But according to Roberts-Austen's own work aluminium, iridium and lithium (all of high atomic volume, yet increasing the tenacity of gold) behaved abnormally, and Arnold and Jefferson had shown in 1894 and 1896 that the atomic volume did not have the direct influence suggested. By studying the microstructure of alloys (gold with lead, bismuth, tellurium), Arnold proved that fragility resulted when each gold crystal was isolated from its neighbors by a cell-wall of the other metal, and that in iron (atomic volume 7.2) the addition of nickel, copper, aluminium, phosphorus, always produced hardness—so long as the second element passed entirely into solid solution—though the atomic volumes of these elements were 6.7, 7.1, 10.5, 13.5. The importance of the atomic volume came in in another way. Silver and gold had practically the same atomic volumes, 10.23 and 10.20, and formed solid solutions in all proportions (as stated); silver and lead (atomic volumes 10.2 and 18.2) formed a series of eutectoids without appreciable miscibility at either end, and in Arnold's iron alloys—carbon, arsenic, and sulphur (atomic volumes 3.6, 13.2, 15.7) caused the separation of phases. These observations were in accordance with Mr. Thompson's view that in a solid solution there was a progressive replacement of the atoms in the space-lattice. Elements of similar atomic volumes would readily replace one another, and thus easily enter into solid solution. When the atomic volumes differed considerably, solid solutions would not be formed. That same theory would account for the extreme hardness of compounds of metals with metals. The interpenetration of the space-lattices would induce in them similar changes in atomic volume, and set up elastic stresses. But as a certain rigidity had to be assumed in the space-lattice of a compound, these compounds would not only be hard, but also brittle.

That many of the leading ideas of these arguments originated with Dr. Beilby, Mr. Thompson accentuated more particularly in his second paper. At the conclusion of his first paper he referred to a recent similar paper by Tammann on "The Molecular Structure of Solid Isotropic and Anisotropic Binary Mixtures." In his second paper on "The Annealing of Metals," Mr. Thompson pointed out that the deformation of the space-lattice as a result of mechanical stress was the first step in the formation of the amorphous modification, and the cause of the increased hardness had to be sought in the amorphous material. That material was either itself very hard, or, what looked more probable, it was the seat of internal stresses. Annealing produced a recrystallization of the deformed structure, and disappearance of the amorphous modification. On that theory the crystalline elements persisting after severe cold work should be no harder than the crystals had been before; that was so, according to Faust and Tammann. Two other theories had been proposed to explain the facts. According to Smits, the applied pressure produced irreversible molecular transformations, so that the physical structure remained different after removal of the stress. According to Tammann, tension stresses were set up in the planes of slip, and the greater the stress applied the greater the number of slip planes and the hardness, ductility being on this view a function of the number of slip planes per unit volume induced by a constant stress.

The annealing of cold-worked metals or alloys (brass, nickel-silver), Mr. Thompson continued, was essentially distinct from the annealing of steel. In the latter case the objective was the removal of stresses due to casting or quenching, the equalization of composition, and the refinement of coarse grain; the elastic limit should be maintained as high as possible. When brass cartridge-cases had to be annealed after cold work, it was to make them capable of receiving further changes of shape. The work required to produce these further changes was first used in causing elastic deformation—which was small and transient, disappearing immediately the stress was removed, and this energy was really wasted; and, secondly, in causing the required plastic deformation; thus, the higher the elastic limit the greater was the percentage of energy lost in useless effort; an almost non-existent elastic limit was the desideratum. That fact complicated the annealing of brass; the annealing was to admit of a further maximum reduction in the rolls or in wire-drawing, and for that purpose re-heating above the temperature at which recrystallization took place was required. To illustrate his point Mr. Thompson gave particulars of experiments with a low-grade nickel-silver (9 per cent of nickel), which, annealed for half an hour at gradually increasing temperatures of 300, 370, 440, 510, 580, 720, 785, 930 deg. Cent. in a gas-fired muffle, gave Brinell hardness numbers of 130, 143, 127, 119, 86, 80, 65, 52, 50; hence, softening began at 370 degrees, but was not complete until the temperature reached 800 degrees. With a 70/30 brass Charpy had similarly found, at temperatures of 200, 280, 420, 560, 600, 832 deg. Cent., maximum stresses (in kilogrammes per square millimeter) of 49.5, 51.2, 46.5, 34, 30, 27.5, 27.5.

When comparative annealing experiments of alloys and of metals were made, it was found that the alloy required much higher temperatures than the metal, and the range over which the softening extended was much greater in the case of the alloy. In the case of the nickel-silver the range extended from 370 up to 800 deg. Cent., while Beilby had softened pure copper within a range of 50 deg., an observation which Charpy had confirmed for copper. There was, further, a noteworthy slight increase in the hardness curves of the copper and alloys just before the commencement of softening; this feature Mr. Thompson had found to be general. According to Charpy, annealing practically did not affect the properties of cold-worked brass up to a certain temperature; then recrystallization, first probably of those crystals which had been most distorted, set in, and continued up to total crystallization at a certain higher temperature. To complete the heat treatment, however, a still higher temperature had to be applied, and there was danger of burning. The burning had a two-fold effect: it induced coarse crystallization and mechanical weakness, though such a metal, as Hudson had shown in 1913, would roll satisfactorily; but there was also fusion and volatilization of the more volatile metal, which was particularly noticeable in the presence of certain impurities. Thus Charpy found that brass was not deteriorated at 900 deg. Cent., but began to burn at 800 deg. in the presence of 0.2 per cent. of lead and 0.15 per cent. of tin. The tests of this impure cartridge brass yielded, at 540, 620, 700, 860, 930 deg. Cent., a maximum stress (in kilogrammes per square millimeter) of 62, 32, 30, 29.3, 27.6, 26.5, and an elongation of 3.8, 55, 61, 65, 57, 56.5 per cent. The loss of tensile strength caused by recrystallization was at first accompanied by an increase in the elongation. When burning occurred, strength and ductility both decreased, and in such brass pits (from the volatilization of the zinc) appeared, which finally developed into fissures. The time factor, i. e., prolonged annealing at low temperature, or rapid heating to a higher temperature was unimportant according to Charpy and Le Chatelier, for wires, strips, and small ingots. For larger samples some time had to be allowed for the conduction of the heat, but the prolonged soaking, occasionally recommended, was probably unnecessary in Mr. Thompson's opinion. The time factor was important for working at comparatively low temperatures, which were of little technical interest, however. Thus hard-rolled copper required an hour's soaking at 200 deg. Cent. for total annealing, but was completely softened in a minute or two at 350 deg. Cent. (Le Chatelier). The diminution of electric resistance and of hardness generally went together in brasses, nickel-silver and other alloys, and also in pure metals. Nickel-silvers of 28 per cent nickel, however, did not diminish their resistance when annealed, and there was also a peculiar peak of high resistance in all nickel-silvers of more than 15 per cent nickel, between 320 and 400 deg. Cent. The minimum resistance observed in nickel-silver of 7 per cent, at 400 deg. Cent., on the other hand, had also been noticed by Credner in many metals—silver, gold, copper, iron, nickel. Sir Robert Hadfield and Dr. Desch commented upon the importance of these communications by Mr. Thompson.

A note by Dr. R. Seligmann and Mr. Percy Williams on the "Annealing of Aluminium" concerned further evidence of changes produced in aluminium at the comparatively low temperature of 125 deg. Cent. Lowry and Parker had observed that hard-worked aluminium (filings) decreased in density when heated up to 100 deg. Cent. Dr. Seligmann has studied the technically important attack of aluminium by nitric acid. The attack, he explained, was very slight, the loss of aluminium amounting to about 56 milligrammes per 100 square centimeters per twenty-four hours, but the corrosion did not stop after a time; heating to 125 deg. Cent. for ten hours reduced the attack by 5 per cent, heating to 500 deg. Cent. by 30 per cent. The rate of dissolution did not diminish on prolonged heating (for eighty hours) at 125 degrees, but when the metal was annealed at higher temperature (440 deg. Cent.) the loss of weight in nitric acid was first smaller than when the metal had been allowed to stand for several days after annealing. Aluminium is, broadly speaking, believed not to oxidize in the air, even when hot, and not to be attacked by nitric acid; as a matter of fact it covers itself with a very fine pro-

* From *Engineering*.

tective film of oxide. In view of these facts, Dr. Borns asked whether the fine oxide film might not have some influence on the corrodibility by nitric acid, but Dr. Seligmann replied that he had guarded against such influences. Dr. Seligmann did not explain his observations by proposing any allotropic modification of aluminium; but Dr. F. J. Brislee did so in a paper on "The Specific Heat of Hard and Soft Aluminium," a continuation of his former work on "Changes in Physical Properties of Aluminium with Mechanical Work."

Color-Vision—II*

And Color-Vision Theories, Including the Theory of Vision

By F. W. Edridge Green, M.D., F.R.C.S.

Concluded from Scientific American Supplement No. 2114, page page 32, July 8, 1916

IX.—PERIPHERAL COLOR VISION.

The erroneous statement is continually made that the periphery of the retina is color-blind. If red light of sufficient intensity be employed it can be recognized as the same red to the extreme periphery of the field of vision. This is exactly what we should expect on the theory given, the less developed portions of the retina requiring a stronger stimulus than the more developed portions.

Much of the experimental work on color vision has been done with bits of colored paper and impure colors, which is similar to conducting a chemical analysis with impure chemicals; many of the results are due to stray light and entirely different results are obtained when pure spectral light is employed.

X.—FACTS SUPPORTING THE THEORY OF THE RELATIVE FUNCTIONS OF THE RODS AND CONES OF THE RETINA.

There is not a single fact pointing to the view that rods are percipient elements. The attribution of this function to them is the purest assumption, and recent writers are now recognizing that this is the case. On the other hand a photo-chemical theory of vision an elaborate nervous mechanism is required to repair and regulate the photograph in various physical conditions. This function is performed by the rods, which contain a photo-chemical substance, the visual purple, which is not present in the cones; they liberate the visual purple into the fluid surrounding the cones, and the decomposition of this photo-chemical fluid by light stimulates the ends of the cones, and the visual impulses are started.

From an anatomical point of view it seems impossible that the rods could be percipient elements. The reader should examine some recent reproductions of microscopic specimens of the retina. It will be noticed that the rods terminate in rounded knobs, many of which are in connection with one neuron. It will also be noticed that transverse neurons connect many groups of rods, and this transverse neuron is only indirectly connected with the ganglion cell leading to the fiber of the optic nerve. Now, in order that any percipient element may be able to act as such, the anatomical paths must be different, but how can the rods act as percipient elements when a large group terminates in the same path? It will be noticed that this anatomical arrangement is perfect from the point of view that the rods regulate the distribution of the visual purple into the liquid surrounding the cones.

The visual purple is found in the rods and not in the cones, but if the external surface of the retina of a monkey which has been kept for forty-eight hours in a dark room, be examined, the visual purple will be found between and not in the cones.

The visual acuity corresponds roughly to the distribution of the cones. Though the rods are much more numerous in the periphery of the retina, visual acuity is very much less with this part.

The Relations Between the Foveal and the Para-foveal Regions.—As there are no rods in the fovea, if the rods and cones were percipient elements of a different character, there ought to be a qualitative difference between these regions. It has, however, been conclusively proved that there are only gradual quantitative differences in the sight between the foveal and the para-foveal areas. The Purkinje phenomenon, the alteration of optical white equations by the state of dark adaptation, the colorless interval for spectral lights of increasing intensity, the different phases of the after-image, all exist, not only in the para-foveal, but also, only gradually diminished, in the foveal region.

Chemical Analogy.—The visual purple gives a curve which is very similar to that of the many other photo-chemical substances. We know that with photo-chemical substances the chemical effect is not proportional to the intensity of light; a different curve is obtained with weak light from that which is formed with light of greater intensity. It is reasonable, therefore, to suppose that the visual purple which is formed by the pigment cells under the influence of a bright light would be somewhat different in character from that which is formed in darkness. Again, from the chemical analogy which I have just given, even if the visual purple were of the same character we should not expect similar curves with different intensities of light. It is probable that both factors are in operation. This deduction gives an explanation of the Purkinje phenomenon. Not only is the visual purple decomposed and regenerated in daylight, but light is plainly a stimulus for its regeneration.

The Varying Sensibility of the Fovea.—At one moment the fovea appears the least sensitive portion, and at the next moment may be the most sensitive portion of the retina. Helmholtz, while recordng the fact, confessed that he was quite unable to suggest an explanation. The following simple experiment shows this fact:

On opening an eye on awaking in the morning and looking at the ceiling the central portion is seen as an irregular, circular, rhomboidal, or star-shaped black spot. On closing the eye again a bluish violet circle appears at the periphery or middle of the field of vision, contracts, and then, after breaking up into a star-shaped figure and becoming brighter, disappears to be followed by another contracting circle. If the eye be opened when the star figure has formed in the center, it will appear as a bright rose-colored star, much brighter than any other part of the field of vision. If, however, we wait till the star has broken up and disappeared before opening the eye, it will be found that only a black spot is seen in the center.

This is explained on the theory that when there is visual purple in the fovea this is the most sensitive portion of the retina; when there is none there, it is blind. It also shows conclusively that the fovea is sensitized from the periphery.

Disappearance of Lights Falling Upon the Fovea.—If we look at two small isolated stars of equal magnitude, either may be made to disappear by looking fixedly at it, while the other remains conspicuously visible. The phenomenon is most marked on a dark night, and when the star looked at is in a portion of the sky comparatively free from other stars, and when one eye is used. On a very dark night a considerable number of small stars occupying the center of the field of vision, may be made to disappear, while stars occupying other areas of the field of vision are plainly visible. This fact shows that when the visual purple in the fovea is used up and not renewed, the latter is blind.

Currents Seen in the Field of Vision not due to the Circulation.—There are numerous methods by which currents in the field of vision which are not due to the circulation can be seen. The following is one example:

If one eye be partially covered with an opaque disk while both eyes are directed forward in a not too brightly illuminated room, and special attention be paid to the covered eye, an appearance of whirling currents will be seen with this eye. These currents appear to be directed toward the center and have a very similar appearance to a whirlpool. On closing both eyes all the portion in which the whirling currents are seen appears as dull purple. These currents cannot be due to vessels, because we know that the center of the retina corresponding to the point where the greatest movement is seen, is free from vessels. The appearance is also very different from that of the movement of blood in vessels. The experiment succeeds best if the eyes have been previously exposed to a fairly bright light. An opaque disk in a spectacle frame suffices admirably, a certain amount of light being allowed to enter the eye from the periphery.

The currents carry the visual quality, color, and brightness of the region from whence they come into an after-image. They also tend to move an after-image toward the center, thus if we have two similar after-images, one situated in the center and the other a short distance from the center, the one external to the center may be carried into the center and combine with the one already there.

These currents are formed by the flow of sensitized liquid.

Movement of Positive After-image.—I have shown how the positive after-image may, by a jerk with the head, be separated from the negative after-image and that multiple after-images can be caused by one light stimulus. This shows that the photo-chemical stimulus is external to the cones and can be moved.

Dark and Light Adaptation.—We have an easy explanation of dark adaptation by assuming that the liquid round the cones becomes more sensitive through a greater percentage of visual purple being poured into it. In light adaptation the anatomical arrangement is such as to prevent as far as possible the decomposition of the visual purple.

The above is only a very small portion of the evidence which might have been given in support of the theory advanced. The reader will find further facts in my papers in the *Journal of Physiology* and elsewhere, and I have stated in the *Journal of Physiology* that this theory should be accepted as the working hypothesis of vision until some fact is found which is consistent with it. I have discussed the theory with the chief workers of the world on vision, and they have not been able to point out any fact which is opposed to. it. Should any reader be able to do so, I should be glad to hear from him.

CONCLUSION.

The reader might like to know my answer to any objections raised to the given theories of vision and color vision. There have never been any, and it is, therefore, difficult to know how to deal with opponents who only stab in the back and will not come out in the open. It is however, a great satisfaction to find opponents who have previously stated diametrically the opposite, now giving my facts and conclusions, even though there be no acknowledgment or even mention of my name. This is the more curious as a steadily increasing number of the ablest scientific men in this and other countries have favored these vews, and text book after text book has adopted them. It is obvious that any theory must explain the facts as they really are.

*Science Progress

The Life and Relining of Guns

The life of a gun is measured by the number of rounds fired beyond which the erosion of the bore impairs the accuracy of fire beyond possible limits. Erosion is produced by the action of the gases at high temperature and pressure. While the time element is small, yet the gun, of course, absorbs heat. This absorption is confined to a thin film of steel on the interior surface. The local heating causes the film to expand, and, there being no room to expand naturally, due to the cooler and thicker wall, the elastic limit is passed and permanent set takes place. Upon the release of the pressure, and in consequence temperature, contraction of the film occurs, and, as it has been crushed, this contraction causes minute cracks. This process continues, the minute cracks getting larger at each discharge. As they enlarge they form by-passes for the hot gas, which tends to further enlarge them. The process continues until the inner surface gets badly roughened and the lands begin to be eaten away. Finally the bore gets so enlarged that the gases can escape, the shell does not attain its proper rotation, and the flight of the shell becomes erratic and subject to errors; when the gun no longer maintains a reasonable accuracy and it is said to be worn out.

All guns except small ones are now constructed with liners in the tube, which, when the bore is worn out, are removed and replaced with new liners. The cost of thus relining a gun can be roughly fixed at 30 per cent of the cost of the gun. There appears to be no limit to the number of times that a gun can be relined; hence the life of a gun is indeterminate. It is, of course, a matter of arbitrary decision as to when a gun should be relined, as the criterion depends solely on what is considered as the accuracy desirable. It is difficult to generalize on the subject. The small arms used in this country are considered to be worn out after 5,000 to 7,500 rounds have been fired. Small naval guns have been fired about 1,000 times before they were regarded as worn out. Large 12-inch and 14-inch naval guns are considered to have a life of one liner of from 150 to 200 rounds. Low-velocity guns, such as howitzers and mortars, have correspondingly longer life than high-velocity guns of the same caliber, because the pressure they use, and hence the temperatures are lower.

As is seen from the preceding, the power and life of guns are functions of each other. The amount of power that can be wisely sacrificed for the sake of preserving the gun is not only extremely difficult to decide, but depends on many factors, some of which are subject to national policy. Taken broadly, caliber for caliber, permanent fortification artillery can be given the greatest power, naval artillery can be given as great power, and field artillery only moderate power.—*L. Cresap, in The Iron Age.*

Figs. 1 and 2.—In the left hand illustration is seen the crusher plant, and the system of track and switches leading to different parts of the quarry. All of the cars shown are being operated from the controlling tower by one man. On the right hand is seen a steam shovel that is served by a succession of single cars, as required, instead of by long trains.

An Electric Haulage System*

Controlling Cars at a Distance From a Central Station

By F. E. Woodford

I AM going to assume that all present are familiar with the general methods of hauling earth or rock and shall not go into descriptions of cable systems, suspension or tractive, or try to draw pictures of a noisy little locomotive puffing its head off as it brings its regular burden around a curve or up a slight incline; but will proceed at once to a consideration of centrally controlled electric haulage systems.

The system of haulage I wish to consider in detail consists in a method of operating a multiplicity of cars used in industrial haulage, from a central controlling tower by remote control, and is applicable to such industrial haulage as is found in stone quarries, open mines, clay and gravel pits and other places where the distance is not too great and where the operation of the cars can be seen for at least part of the time from the controlling tower.

The cause which led to the development of this system was a study of haulage methods which have prevailed for a great many years in the institutions mentioned. Where the tonnage required it, locomotives have been used for industrial haulage almost universally. It is true that a few cable ways have been installed, but owing to the necessity of track shifting and other conditions prevalent in quarries and open mines, these systems are very rare.

In a certain locality in the South it was attempted to operate a number of cars over a circular track without motormen or operators upon the cars. The cars were to be loaded upon one portion of the circle and unloaded at a fixed point upon another part of the circle. The cars were equipped with three-phase induction motors, using the track rails for one line and two other rails as "third rails" for the other two lines. It was intended to place a certain number of cars upon the track at regular distances apart, starting and stopping all the cars at the same time, one being loaded and the other being dumped. The operation was by starting switches at a remote point. This attempt failed completely on account of the high starting current of the induction motors and the enormous overload imposed upon the generating plant by starting all the units at the same time, as well as the fact that it was impossible to maintain the regular positions of the cars in their respective places.

A partial success for handling a smaller amount of material than was intended was finally accomplished by using one third the original number of cars and by equipping each car with a starting switch. By this method and by running the cars very slowly, a man at the loading point was able to pull the switch on a single car, stopping it for loading, while another man at the dumping hopper was able to do the same thing.

In another instance in the West it was attempted to install a haulage system operated by remote control, using direct current motors and solenoid brakes. While it was very easy to operate the motors by remote control, the brakes failed to work; and, as the cars were stopped in one place only, a sliding element under the cars was installed at this point and operated by a lever. This sliding element was a retarding device such as is commonly used to stop cars operated upon scenic railways, roller-coasters and the like.

The motors were started and stopped like traveling cranes operated from another part of the building, in which both armature and field leads connect with a traveler running on separate third rails or feeders, thus supplying the means of operating in both directions, but compelling the use of four separate feeders for the entire length of track.

To develop a system of central control, therefore, which would be adaptable to industrial haulage of all kinds, and which could be installed and maintained at a cost not to exceed that of locomotive haulage, it was necessary to develop apparatus for the cars that would enable them to perform all the functions of the motor car with an operator upon it, or cars that could be operated in both directions and be stopped and started upon any part of the track, and such operation be accomplished by using a single third rail, which could be placed in the center of the track and not be an encumbrance to track shifting and track extension.

Considering the stone quarry as an example where probably the greatest tonnage of material in any industry is handled, we find that during the past few years their equipment has been increased in size and capacity perhaps more than any other industry, until, at the present time, we find initial crushers that will take from 5,000 to 6,000 tons of stone in ten hours. With the average distance from the quarry to the plant, this capacity requires from twelve to sixteen 35-ton locomotives and perhaps seventy-five cars carrying ten cubic yards each. These locomotives mean upward of 500 tons of dead weight transported over the track at each trip with the corresponding power required to propel them. This is in addition to the cars and the product to be carried.

It is a well-known fact that the draw-bar pull of a locomotive is directly proportionate to its weight, consequently it will readily be seen that the elimination of the locomotives and the placing of the load on top of the tractive machinery will very materially reduce the power cost of any haulage system, regardless of conditions of the track, grades or method of operation.

Locomotive haulage again requires two men for each locomotive and train, besides some switchmen, or about thirty men for handling such quantities of stone as the present crushing machinery is able to take. Labor cost consequently is greatly reduced by means of central control, where one man is able to handle all the cars in such a system.

It is very common practice in quarries of this size for locomotives to handle a train of six cars. Each car in the train, therefore, either before loading or after being loaded must wait for five other cars to go through the same process. This condition is repeated where the cars are dumped into the crusher. Each car, therefore, loses by waiting ten times the length of time required for its own operation. With tractive power upon each car, and by not having to wait at the loading or unloading point, practically only one tenth of the number of cars of the same capacity are required as for locomotive haulage, as each car makes a great many more trips than it would if the cars were handled in trains.

These three factors, reduction in power cost, reduc-

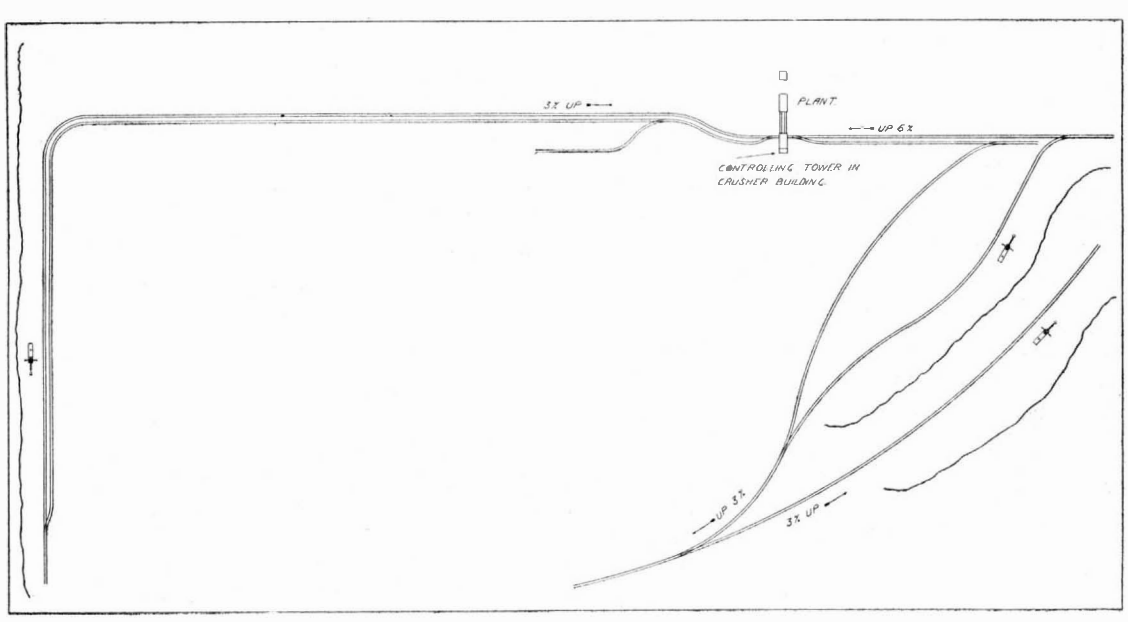
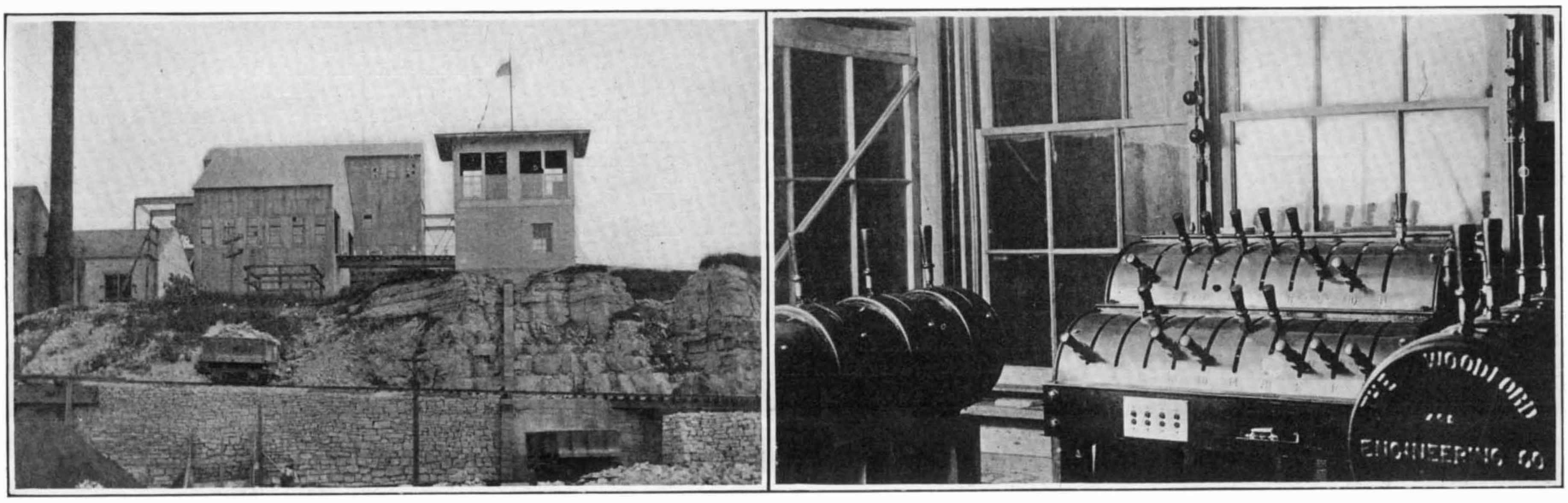


Fig. 3.—Typical plan of the arrangement of tracks in a quarry.

* A paper read before the Engineers Society of Western Pennsylvania, and published in the *Proceedings* of the Society, pp. 584-597, 1915.



Figs. 4 and 5.—On the left is the controlling tower. One of the cars is ascending the grade to the crushing plant, while the other is returning empty to the quarry. On the right is shown the switches in the tower, by which one man controls the entire transportation and dumping system.

tion in labor cost and the decreased amount of rolling stock, comprise the elements that entered into the development and perfection of a system of haulage which can be operated by one man.

As a preliminary to a general description of the elaborate system under consideration, I would give the following:

Each car carries its own motive power and control apparatus, taking current from a sectionalized third rail, which allows the car to be started and stopped, or have brakes applied at the will of tower operator, and the car to have its direction reversed at certain fixed points. Control apparatus on the car is arranged so that as the car descends grades the motors can be connected across resistance banks and the regenerative effect used for retardation purposes.

The third rail, which extends over the whole territory covered by haulage system, is divided into long or short sections, as conditions require, and an independent feeder is extended from the control tower to each section. Tower operator has two voltages, 250 volts and 90 volts, which he can apply to various sections of third rail at will. Two hundred and fifty volts are used for haulage purposes and 90 volts are for braking purposes. The regular car rails are used as a return circuit.

The tower apparatus consists of a switching mechanism by means of which the tower operator may put haulage or braking voltages on sections of third rail, or allow them to stand without applied voltage. In the tower machine there are also, when desired, control switches for operating motor-driven track switches, reversing switches and other special apparatus located at distant points on haulage system.

In order to better describe the operation of the system I would like to describe a single installation, and would therefore refer to the system installed at Kenneth, Indiana, where conditions were so varied as to make this installation meet practically all haulage conditions.

The initial crusher at this plant, into which the rock from the quarry is dumped from the cars, is one of the largest jaw crushers built at the present time. Stone is brought from two separate quarries in opposite directions from the crushing plant, over tracks of standard gage, as shown in Fig. 2. Three shovels are located in the two quarries, with double tracks leading from the shovels to the crushing plant, the location of tracks being determined by the conditions, and shifted as the quarry is developed. The track in the quarry at one of the shovels is approximately thirty-five feet below the track at the crusher, the rise being made over a 10 per cent grade on that portion of the track approaching the crusher.

The third rail, or power rail, is placed between the two track rails and insulated in the manner employed in regular electric traction practice. As stated before, the track rails furnish the return conductor and are bonded in the usual manner for service of this class.

The third rail is divided into different sections, the sections at the crusher and near the shovel being considerably shorter than those of the rest of the track. Each of these sections is bonded in the usual manner and each has a separate feeder connection with the controlling tower. The controlling tower in this instance was placed at the crusher, and one operator at this point is able to operate and dump all the cars in the system, the cars being dumped by a motor-driven hoist operated from the same tower.

Each car truck is fitted with two railway type, 250-volt, direct-current series motors, mounted upon the axles and supported by suspension springs and connected with the axle through single reduction gears in the ordinary manner adopted by electrical traction practice. These motors have their shafts extended at the commutator ends and carry a specially designed solenoid brake, which is applied by the action of the solenoid and released by springs. The car truck also carries three other pieces of apparatus necessary for the operation of the cars from a central point. They are a bank of resistance, a double pole double throw switch for reversing the direction of the motors, and an electric relay or selector switch. This selector switch is a solenoid-operated switch having two contacts and two positions. It is locked in its gravity position with one contact open and one contact closed. In its position induced by the solenoid it is also locked, opening the gravity circuit and closing the other circuit. The solenoid will not respond to a voltage lower than 175, but after being closed will hold in with 50 volts, or even less.

The motors are operated with the selector switch in its excited position. The circuit in the gravity position is to the brake solenoids, and the relay will remain locked in gravity position while the brakes are applied. While the relay is in the gravity position it also establishes a circuit from the motors on the car to the bank of resistance which the car carries. This resistance is adjusted to dissipate the current generated by the motors running as generators while the car is traveling down a grade, thus furnishing a dynamic brake for the cars which is not under the control of the operator. This feature forms a safety device should the circuit breaker go out while the car is ascending the grade, as upon circuit breaker opening the car will merely coast back down hill at a not excessive speed. While the operator has control of the brakes at all times, this feature also relieves him of governing or speeding the car while it is traveling down the grade. This feature renders the system semi-automatic, arranging its operation so that it is necessary for the operator to give very little attention to the running of the cars except where they are stopped for the loading or unloading.

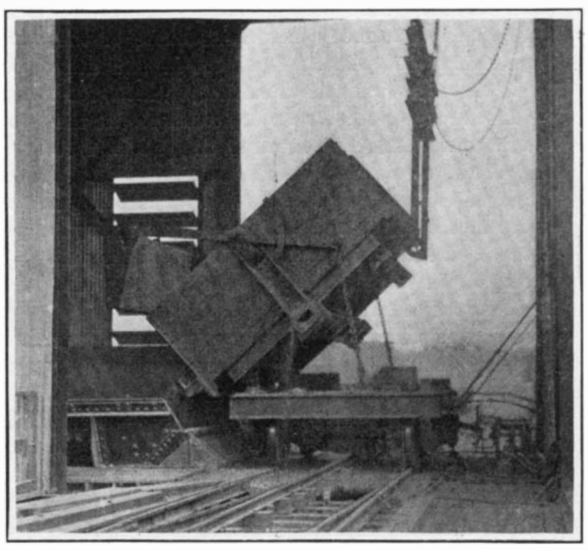


Fig. 6.—Dumping a car at the crusher.

Each section of third rail is excited separately by the controlling mechanism through master control. The controlling system consists of ordinary magnet switches with magnetic blowouts, a bank of distributing switches and controlling levers, assembled in units of three and four levers each. The lever is off in its central position. The forward arc controls the motors through the contactors, that section of third rail being excited as the magnetic switches close through resistance which is placed at the controlling point. A dash pot switch is operated by the controller lever, through the arc of motor control, in such a manner as to open all the magnet switches by a backward movement of the controller lever from any control point. The backward movement of the lever from its central position is through the arc of brake control and excites the same section of third rail directly through resistance, giving a range of from thirty to a hundred volts.

These excitations from the same lever are conducted to the third rail feeder through a bank of distributing switches which consist of a certain number of hand-operated switches, one switch for each section of third rail. Thus, from the central controlling tower, placed at any convenient position, we are able to excite any section of third rail with a voltage ranging from 30 to 100 for controlling the brakes, as well as with the starting and running current for the motors. An interior view of the controlling tower is shown in Fig. 5.

A reversing switch is placed on the car so that it is operated by a lever protruding from the side of the truck in such a manner as to engage track cams placed at desired locations along the track, at track switches where all the cars are to be reversed. At points along the tracks where it is necessary for only part of the cars to be reversed, this reversing cam consists of forgings and levers having two positions and operated by a solenoid. Should it be necessary to reverse the car, this solenoid is excited from the tower by a foot switch. It will readily be seen that by this method operation in any manner to meet any conditions may be accomplished, and with track cams at the top of all grades it is impossible for a car to enter upon that grade without the reversing switch and selector switch being in proper position to cause the motors to generate current as they are propelled by the momentum of the car, and furnishing the dynamic brake, maintaining a fixed speed at all times.

At the dumping hopper or crusher another form of reversing cam has been adopted, which is thrown into different positions by a motor-driven movement. This cam carries parallel bars some 10 or 12 feet in length between which the reversing lever of the car passes so that the car may be spotted in any particular position for dumping, arriving from either direction and leaving in either direction. This motor-driven cam is also operated by push-button switches from the tower.

The dumping device, Fig. 6, consists of a motor-driven hoist turning a cam shaft, the cams of which are connected through chains to an I-beam carrying two hooks which engage the inside of the car as they are drawn up by the hoist, and this is operated from the tower through master control with limit stops, limiting its run in either direction, and requiring the operator simply to start it in either direction.

The elements described above, together with centrally controlled, electrically operated track switches, with which all are familiar, render this system of control sufficiently flexible to meet any and all conditions and brings its operating levers within the reach of a single man. A car may be switched to any track; may be run into a passing track from the main line; may be stopped and started from any point and, in fact, operated in the same manner as though there were a motorman upon each car.

The design of a car to carry this apparatus is not materially different than the standard construction of dump cars to which in many cases the motors and other apparatus have been applied.

In the operation of a steam shovel and cars of a size adapted to the shovel capacity, it has been found that four cars will serve a shovel at a distance of half a

mile from the crushing plant and keep the shovel in continuous operation. This means a great reduction from the number of cars that would be required for locomotive or train haulage. It will also be seen that the controlling levers and mechanisms are not a multiple of the car units, but are rather in proportion to the amount of track and the conditions of operation. With a sufficient amount of controlling apparatus, therefore, changes and extensions of track may be made without any other change in the system whatever, and an increase in haulage capacity may be accomplished by simply adding cars to the system. This feature renders the system adaptable to whatever conditions may arise and renders available the use of short tracks and spurs that cannot be entered by more than one car at a time.

It has also been found that the capacity of the steam shovel is materially increased by supplying cars individually, keeping a succession of cars approaching the shovel and enabling the shovel to operate without waiting for a train to be pulled out and another pulled in, as shown in Fig. 2.

The power cost, of course, depends directly upon the tonnage, the distance from the shovels to the crusher and the vertical elevation of the crusher above the quarry floor. These three items being different in all cases, it has been impossible to obtain an exact power cost that would be useful in a general way. The power cost for each proposition, therefore, must be computed individually. But on account of the power cost being a very low item, and the fact that the labor cost of operation is the same in all instances, it has been found that a fair average for operation and up-keep of the haulage system is not over one half cent per ton mile in all except very small installations.

The installation cost compared with that of locomotive haulage has been found to be practically equal with a capacity of 3,000 tons in 10 hours. For smaller capacities the installation cost of an electric haulage system has been found to increase gradually above that of locomotive haulage, while above 3,000 tons capacity it has been found to be somewhat less.

The "safety first" principle is embodied in the fact that there are no men around the cars while loading or unloading, and it is not necessary for laborers to be on or near the tracks at any time when the system is in operation. And the flexibility of handling material while the shovel is in an end cut and such parts of the quarry as are otherwise wasted from their being inaccessible by a locomotive and train, furnishes the last of many arguments in favor of industrial haulage operated by central control.

Aurora*

Earth Currents and Magnetic Disturbances

By Otto Klotz

THESE may all be treated as a common subject or phenomenon. Let it be stated right at the outset that our ignorance of them is still vast.

The following despatch from Winnipeg on June 17, 1915, is so interesting that it is inserted in full, besides giving an opportunity for explaining some of the statements made therein:

"Aurora, more mysterious than wireless telegraphy, less constant than the visible manifestations of electrical storms, is to-day tangling up all the telegraph wires strung across the top of the continent, more especially those along the north shore of Lake Superior. There has not been such a complete tie-up in the telegraph business between eastern and western Canada for a long time, and possibly records for the month of June might be searched for many years back without finding a parallel. In fact, well conducted auroræ confine themselves to the fall and winter months, and of all the months in the year June is most immune. The record of observations in Scandanavia and Iceland, as well as the Spitzenbergen Station, show no aurora at all in June, though on the North American continent it is not an unknown, though still a rare June phenomenon.

"Aurora manifestations are almost entirely confined to night, and these manifestations, whether visible or not, are commonly accompanied by magnetic earth currents, and it is these properly that affect the wires. Usually with the morning sun the whole manifestation lifts, wires surcharged with excessive and variating currents are freed and released for their daily business and the atmosphere, overloaded with electricity, becomes normal. But to-day the magnetic storm, potent though both unseen and unheard, is raging as furiously, to the tune of crackling wires at noon, as it was at midnight. The sky is heavy and overcast. When the clouds lift and sun breaks through, the whole trouble will vanish magically as it came. For generations scientists have sought the secret of aurora and earth currents but have learned little beyond the central fact of the inconstancy of all available data on the subject.

"Another peculiarity of the present visitation—a scourge alike to the telegraph companies and the daily newspapers—is that, whereas usually it is only wires running east and west that are affected by the polar visitant, on this occasion wires running north and south, such as those between Winnipeg and Minneapolis, are affected to nearly the same extent. From the meteorological point of view, this magnetic storm adds one more to the queer performances of the current month of June."

The first and natural question to occur to an observer beholding the aurora, a brilliant aurora with its dancing, shooting streamers; building, forming and dissolving; rushing from its northern arch to meet beyond the zenith; clothed, perhaps, in greenish gauzy drapery or yet in portentous red; ceaseless activity, a mysterious phenomenon, bewildering to mind and brain—what is the aurora? Beholding it, gives no answer, but when we compare the phenomenon with associated ones we learn a little of its nature. We find it to be electric in its nature, an electric discharge. But here our positive knowledge about its nature stops.

We may mention the theories that have been advanced to account for the aurora. Birkeland attributes the phenomena as due to cathode rays emanating from the sun; Nordmann replaces the cathode rays by Hertzian waves; and Arrhenius supposes negatively charged particles to be sent out by the sun and reaching the earth, ionizing the upper regions of the atmosphere and thereby making it a good conductor for electrical discharges. The cathode rays we know travel at about a tenth of the velocity of light, hence would take nearly an hour and a half to reach us from the sun; the Hertzian waves travel at the velocity of light, i. e., 186,000 miles a second; and Arrhenius' particles would take about 46 hours, about 2 days, for transmission. The transmission time forms an important factor when an attempt is made to associate particular sun spots and solar outbursts with particular auroræ and magnetic disturbances. The solar effect is, that the discharge of the difference of potential on the earth is greatly facilitated; we have an electric current established with its consequent phenomena of auroræ, earth currents and magnetic disturbances. These are all more or less influenced by local conditions on or in the crust of the earth, and hence vary in intensity at different places. However, the strong currents encircle the earth, as we see in some notable cases, and manifest themselves particularly in magnetic disturbances and earth currents.

The electrical discharges, for, of such are the auroræ, where do they take place? Many measurements and photographs (Störmer) have been made of the aurora to determine its position—height—in our atmosphere, and it has been found that the height, although varying considerably, is of the order of 50 miles. At that elevation the atmospheric pressure is only about 1/500 of an inch, about the pressure in a Geissler tube. The discharge of electricity through highly rarefied gases and vapors in the large tubes, with the accompanying glow, at the Centennial Exposition, in 1876, impressed the writer at the time with its close analogy and resemblance to the aurora or northern lights.

We may look upon the sun, not as the source of the magnetic disturbances, but as the medium that sets loose the bound energy residing in and on the earth.

It will generally—although not always—be found that the center of the aurora-arch, if there be one, is in the magnetic meridian. In eastern Canada and the eastern United States this will be west of the true or astronomic north, while west of Lake Superior to the Pacific it will be east of the true meridian. Furthermore, if the streamers ascend from the north toward the zenith or beyond it, it will be found that their focus or meeting place is beyond or south of the zenith, and at a point approximately where the direction of the dipping needle intersects the celestial vault. We see here then a pretty close connection between the aurora and compass and dipping needle, which we know otherwise to exist. It is fairly safe to say that there is never a bright auroral display without an accompanying magnetic storm, and for which many cases might be cited. The inverse of the statement—that with every magnetic storm we have auroral display—is not so obvious, because the magnetic instruments are always at work, being self-registering, independent of day or night, while the aurora is a matter of visibility, and hence observations are relegated practically to the night. Here we may cite a most interesting case—that of the great auroral display and great magnetic storm of June 17 last. Prof. E. E. Barnard, in *Nature* of July 15, gives a vivid description of the aurora as seen at the Yerkes Observatory. The maximum brilliancy was reached shortly after 2 A. M., Central Standard Time, and shortly afterwards dawn blotted out further observation. While the aurora was pursuing its magic performances in the heavens the magnetic instruments all over the world were mightily perturbed, and as we know from the Winnipeg despatch quoted and other press reports, the telegraph lines were more or less demoralized by the atmospheric electric currents. While dawn was breaking with us, night was approaching in New Zealand, so that this world-encircling phenomenon could be observed there after daylight had made it invisible in America. And this is what happened. While it was mid-Summer with us, at Dunedin, latitude 46 degrees south, longitude 170 degrees east or 11 hours 22 minutes ahead of Greenwich, it was mid-Winter, and the sun set before 5 P. M. Standard Time in New Zealand is fast on Central Standard Time 17 hours 30 minutes, so that 2 A. M. quoted by Barnard would be 19:30 or 7:30 P. M. in New Zealand.

Mr. W. E. McAdam of Dunedin writes:

"Upon that day (June 17) there was an exceptionally fine display of the Aurora Australis visible all over New Zealand. Here at Dunedin it commenced at 7:30 P. M. and lasted till midnight. The glow in the southern horizon was quite uncanny in effect, producing the illusion that the sun was about to rise in an impossible quarter of the sky, and at an impossible hour. I have been resident in the Southern Hemisphere off and on for 50 years, and have never seen anything to equal the last display of the Aurora Australis, a somewhat rare phenomenon, in the latitude of Dunedin, 46 degrees south.—(*Nature*, September 30, 1915.)"

This is a most interesting case, showing that while the "movies" became invisible in Canada, the night of New Zealand revealed their continued presence.

The aurora does not distribute its favors equally over the earth. The tropics and semi-tropics are practically devoid of them. The curves of equal frequency dip considerably farther south in America than in Europe. No country is so favored by this ethereal visitant as is Canada. From what has been said it is obvious that more auroræ will be seen and are seen during the Winter months than during those of the Summer, simply because in the former case the nights are longer and consequent visibility of the aurora, if there is one.

The aurora has often the appearance of filaments or streaks of clouds, but the distinction is readily observed by the presence of a star or stars behind; for the transparency of the former dims but little, if any, the brightness of the star, which by the latter, even if filmy, would be more or less obliterated.

In tabulating sun-spots and the frequency of auroræ over a long period of years, it is found that there is a very general agreement between the maximum of the one and the maximum of the other, and similarly between the minima, but the definite relationship between the two is not known. Auroræ, magnetic disturbances and earth currents are simultaneous phenomena, due to electric currents in the higher regions of the atmosphere. Their individual intensity is to a degree dependent on local conditions, such as difference in geological formations, and all follow in a general way the sun-spot cycle of 11 years.

In examining the spectrum of the aurora it is found that there is one rather prominent line in the yellow-green wave-length 5,571 which coincides with a prominent line in the spectrum of krypton.

The writer has seen many auroræ in our North-West, their home, and has conversed with Hudson's Bay Company officers and voyageurs, from whom information is said to have been obtained that noises have been heard during auroral displays, and which has been quoted in books and articles on the subject, yet the writer is convinced that there is no authentic record of any noise ever having been heard, although subjectively the "noises" may have been *felt*.

*Journal of The Royal Astronomical Society of Canada.

The interference of earth currents with the working of telegraph and cable lines is largely overcome by making a metallic circuit and thereby cutting out the earth. This, of course, reduces the capacity of the service.

Prof. Barnard reports that signals on June 17, during the aurora display, on the wireless receiver at the observatory were not affected, and that the static conditions were normal.

With reference to earth currents and cables, the writer may be permitted to quote extracts from his official report in 1892, in connection with the trans-Atlantic determination of longitude. At that time there were 10 cables across the Atlantic, but when earth currents set in they are not all equally disturbed, in fact, sometimes some of the cables not at all. The French cable from Brest to St. Pierre seems to be disturbed the most, and again the disturbances are felt to a greater extent at St. Pierre than at Brest. It often happens that St. Pierre can send messages to Brest but cannot receive any. Long cables seem to be more affected than short ones, and, furthermore, the earth currents appear to travel mostly from east to west. When the aurora is visible, it is pretty certain that earth currents will show themselves. Thunderstorms and they, however, do not seem to be so closely related, if at all. During the past season (1892) on July 16, there was a remarkable disturbance noticed at Canso, stopping all work completely. The greatest "kick," as it is called, was given at 12:20 P. M., E. S. T., or 5:20 G. M. T. Some weeks afterwards reports came in the technical journals, from Brest, Malta, Cairo, Madras and east to Singapore of a similar disturbance on that day. Cairo, Egypt, fortunately stated the time, and from it it was found to have been simultaneous with that of Canso. On August 24 (1892), strong earth currents set in at Canso, and at the time there was a marked auroral display. The southern cable (Commercial Company) was far more affected than the northern one. As most of the companies have 2 cables, they can generally get rid of the effects of earth currents by looping the cables together, that is, by making a metallic circuit. Sometimes the earth currents are so strong as to injure the condensers. From the direction of the cables it is noticed that cables running east and west are more troubled with these currents than cables running north and south. There is, however, a wide difference on east and west lines. The superintendent at St. Pierre told me that he experienced more earth currents in the past 2 years (1891, 1892) at that place, than in the preceding 18 years at Torbay and Canso, N. S., and besides that they are felt more on the American than on the European side. And furthermore:

"The cable is quite unprejudiced and shows equal favor to positive or negative gallantries. They are of the most erratic nature; sometimes they take off their things and make quite a visit, 1, 2 or 3 days, varying greatly in their demonstrativeness during the time, but seldom getting so bad as to totally stop traffic. Sometimes they favor us with a 2 or 3-minute call only, as if to remind us that they are still alive. They fluctuate in degree very greatly. The strength or electro-motive force of these earth currents has run up to 500 volts."

We have now said considerable about the subject of this paper, yet have, undoubtedly, failed to answer all the questions of the "practical" man. The practical man wants the aurora, earth currents and magnetic disturbances stopped, for they interfere with his work; the scientist doesn't want them stopped for they are a stepping stone leading upward toward unravelling the grand mechanism of nature. All life, all activity, all energy of the earth, we may trace back to the sun, and until his secrets are revealed we shall remain in ignorance of much that is going on, on our globe. At present our hopes are especially centered on Mount Wilson, where Prof. Hale and his assistants are bending all their energies upon our central orb. They intercept every messenger coming from the sun and put him through a rigorous examination, what his business is, and what despatches were entrusted to him before he left home. All these despatches are written in hieroglyphs, and only for a few, as yet, has a Rosetta stone been found for their interpretation. No gained ground is ever lost by the scientist; he is ever on the offensive. Of the messengers sent out by the sun, the earth intercepts but a very small portion; less than one two-thousand-millionth.

Until some of these messengers have been made to reveal their secrets, until then, we can only conjecture as to the why of the aurora, earth currents and magnetic disturbances.

Vitamin Solution of the Pellagra Problem*

A NUMBER of writers[1] have suggested the possibility of the solution of the pellagra problem in a vitamin removed in the process of milling, but there has been no experimental or clinical evidence worthy of serious consideration.

There is no doubt in the minds of a large number of the students of pellagra that the deficiency theory of Dr. Joseph Goldberger[2] is correct. This report is based on the correctness of his theory. The present work had its inception in an idea suggested by Dr. Goldberger pointing out the analogy between pellagra and beriberi. Reviewing the beriberi situation as it stands at this time, one is impressed with the fact that it is not essential to eat rice in order to suffer the disease, but that it is highly improbable that beriberi will ever become a great economic problem except in rice-eating countries though sporadic cases are occurring even in this country. With this idea in mind, one naturally turns back to the old theories that pellagra was caused by defective corn. An effort was made to determine if corn suffered in the milling process. The work was planned entirely from the standpoint of a deficiency, and developments soon justified the strong suspicion that the protective vitamin was removed by milling, just as the vitamin is removed in the milling of rice when the product is polished rice.

Until recent years,[3] in the South especially, corn was simply crushed between two stones, and the only thing removed was the coarse particles of outer skin or husk. This method of milling has been largely replaced by steam or electric milling. By this process the corn is subjected to heat in order to loosen the outer coarse husk. Our attention at this time is directed to this portion of the industry to determine how much heat is employed. In the modern mill, in which these observations were made, the heat is a negligible quantity; but it must be remembered that 120 deg. Cent. is sufficient to destroy any vitamin that may be contained. This part of the work, therefore, cannot be too strongly emphasized. After the heating process the grain is passed into a "degerminator," which removes the germ. This is done because the germ contains such a large amount of fat that rancidity would soon occur if it were left in the meal. Besides this, the germ would give to the meal a yellow color which by modern standards is counted undesirable. The offal, which contains the germ, husks and bran, some flour and flinty portions of the grain, constitutes about 30 per cent of the entire weight of the grain. It is known as "corn chops," and is fed to the cattle. The remaining endosperm, after the removal of the offal, is finely ground, and the product is known as granulated corn meal; but in this article it will be referred to as milled meal.

Nightingale[4] found that prisoners who had been fed on whole meal ground in the jail did well, and were free from disease. Owing to a crop shortage, he was forced to use milled meal, and there soon developed a disease for which he coined the term "zeism," thinking it to be an undescribed condition. The symptoms were symmetrical erythema of the exposed portions of the body surface, sore mouth, digestive disturbances with diarrhea, and even mental symptoms. He says that it somewhat resembled pellagra, but was not that disease, even if an acute form of it occurred. In 1905 the failure in making the diagnosis was because we did not recognize an acute form of pellagra which is unknown in European literature. A careful reading of Nightingale's paper will convince any one who has seen pellagra in America that this disease could not be otherwise diagnosed. Certainly if it is not pellagra, then the disease going by that name in the United States has been erroneously classified. No better animal experiment will ever be done than this experience of Nightingale to confirm the correctness of our belief that the protective vitamin is removed from corn by the present method of milling. He says that after he found that commercial corn meal caused the trouble, he secured a fresh lot of corn and had it hand milled in the jail. The result of its use is declared "immediate and magical."

Following the general plan of investigation in polyneuritis gallinarum, pigeons were selected for feeding experiments. One group was fed the best commercial meal on the local market. The result was very striking. Polyneuritic symptoms developed almost at once, and other symptoms which are exceedingly suggestive of pellagra. The next group of pigeons was fed on the best corn, which was not kiln dried, and it was ground in the laboratory at the feeding time. These pigeons have made a striking contrast with the former group. In spite of the fact that the only food allowed was corn, they have remained perfectly healthy and active.

In a search through the mountains of North Carolina, I have found no cases of pellagra in those counties removed from the lines of railroad travel. The mountaineer lives on much the same food and in equally as unhygienic conditions as the lowlander, but there the difference in the corn is again quite striking. The mountaineer is too far away from the railroad to get milled meal, so he must send his corn to the local mill, where it is ground in small amounts at a time, and the whole grain is eaten, giving him the necessary protective substance. The man in the low country can get the meal from the village store, and thereby save the time and labor of a man and a mule to send to the mill. In so doing he fails to get the protective substance, and unless his diet is otherwise adapted to supplying the vitamin, pellagra should naturally follow. In an eastern country remote from railroad travel, there are broad areas where pellagra has never been seen, and it is notable that the people eat water-ground whole meal. In all other respects this country seemed to be peculiarly suited to pellagra, and the fact of its absence has always been very puzzling.

Beriberi occurs sporadically among those who never eat rice, but it will never be a great economic problem except in those countries in which rice forms the chief food. Pellagra, likewise, may occur in those who never eat corn, but will probably never reach any proportions except in corn-eating people. Both diseases are deficiencies, and the deficiencies may, and frequently are, made up by other wholesome vitamin-supplying foods, even when deficient grain is eaten.

*Edward Jenner Wood, in a note from the Public Health Laboratory of the City of Wilmington and County of New Hanover, North Carolina.

[1]Castellani and Chalmers: Manual of Tropical Diseases, Ed. 2, 1913. Stitt: Diagnostics and Treatment of Tropical Diseases, 1914.

[2]Goldberger, Joseph: Pellagra: Causation and a Method of prevention, *The Journal* A. M. A., Feb. 12, 1916, p. 471.

[3]Farmers' Bull. 298, U. S. Dept. Agric.

[4]Nightingale: Zeism: A Disease Caused by Defective Mealie Meal, *Transvaal Med. Jour.*, July, 1912.

Photographic Effect of Luminous Watches

FOR obvious reasons watches with luminous dials are extremely popular among military men, especially in the form of the wrist-watch, which is always at hand for instant inspection by night or by day. The luminous substance with which they are treated is stated by the maker to contain radium, and this circumstance may occasion a certain inconvenience at times, for the reason that the rays from radium, like x-rays, are capable of penetrating non-transparent materials and affecting photographic plates or films.

Thus a package of undeveloped plates might be clouded or obscured by the proximity of such a watch.

In order to determine just how serious such interference might be a German photographer, Mr. Carl Schürer, made a series of experiments, of which he gives a report in *Photographie für Alle.*

In his first test a luminous wrist-watch was placed in a dark room with the dial turned down for one minute on the uncovered sensitive side of a highly sensitive photographic plate. When this was developed it showed a clear image of the dial. Obviously, therefore, such a watch should not be worn while the operator is developing plates or films.

In a second test the watch was again laid upon the film side of a highly sensitive plate, but the latter was wrapped in a piece of the black paper taken from the plate box. The plate was developed at the end of 24 hours. It plainly showed a blackening due to radioactive influence operating through the black paper. In this case the center was clouded by the action of the hands, which were moving throughout the 24 hours.

A third experiment was made to determine the degree of protection afforded by pasteboard (of the plate box) and by thin metal sheets. A highly sensitive plate was again wrapped in black paper. Upon that side of the paper lying next to the sensitive side of the plate there were placed a rectangular piece of pasteboard about 2 millimeters in thickness, cut from a side of the plate-box, and a piece of tin-foil (from a cake of chocolate) of equal size, the two being pasted together with joiners' glue. The luminous watch was then so placed that about a fourth of the dial was covered by pasteboard and the adjacent fourth by tin-foil. After remaining thus for 24 hours the plate was developed. It was then seen that the pasteboard afforded but slight protection, while that given by the tin-foil was surprisingly small. The experiment shows, therefore, that the radioactive rays from the watch are tolerably "hard" (as the term is used in Roentgenography).

In a fourth experiment the watch was enclosed in a cigarette box of lacquered tin, and this was laid on the sensitive plate wrapped in black paper. It was left thus for 3 days, and the plate then thoroughly developed, but no trace of blackening was observable.

The conclusion reached is that when wearing such a watch plates and films must be carried in boxes made of comparatively heavy metal.

Shrapnel Shells

How They Are Designed and Tested

By George P. Jewell

WITH the exception of the time fuse the construction of the shrapnel projectile is relatively simple, but like most simple mechanical things care in design and in manufacture are necessary to secure satisfactory results. The general principles are now so well established that a tentative design closely resembling the finished can usually be laid down without difficulty and it is merely intended to outline the steps in checking up and testing such a tentative design.

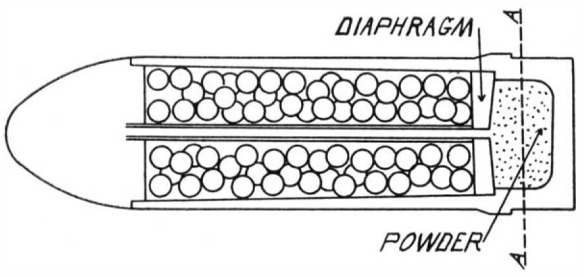


Fig. 1.—Typical 3 inch, fifteen-pound shrapnel.

The 3-inch, 15-pound shrapnel shown in Fig. 1 will be taken as an example and assumed to be fired with a maximum powder pressure of 30,000 pounds to the square inch or a total pressure on the base of the shrapnel of 211,000 pounds. Assuming that the walls at the section *A-A* have a thickness of ½ inch and that 14 pounds of the weight of the shrapnel are in front of this section, the total pressure on this section at the instant of firing will be 14/15 x 211,000 or 197,000 pounds, and this divided by the area of the section gives a unit pressure in the walls of 50,000 pounds, which is safe for the high quality metal of which the case is made.

The diaphragm must carry the load of accelerating about 7 pounds of balls and matrix or 7/15 x 211,000 or 98,000 pounds. The diaphragm is a circular disk uniformly loaded and its strength may be computed accordingly. Fig. 2 shows a fixture for testing diaphragms for strength. It is not desired that the balls should shift or "set back" at the time of firing, and at least the balls nearest the diaphragm may be pressed into the case with a pressure which is greater than that which will be on the diaphragm at the time of firing.

When the shrapnel is exploded in the air by the time fuse the action is much like that of a shotgun, the case corresponding to the barrel, the powder in the base to the charge of the gun, the diaphragm to the wad and the balls to the shot. The pressure in the chamber at the base of the shrapnel at the time of exploding is about 20,000 pounds per square inch, and the unit stress in the walls at the section *A-A* due to this pressure is given by the formula:

$$S = \frac{(4R_1^2 + 2R_0^2)P}{3(R_1^2 - R_0^2)} = 58{,}600 \text{ pounds.}$$

R_0 = interior radius.
R_1 = exterior radius.
P = interior unit pressure.

This formula is strictly true only when the stresses are within the elastic limit of the metal. The remainder of the walls are correspondingly thinner for the same reason that a gun barrel is thinner near the muzzle.

It is assumed that at the time the gun is fired the balls act as a fluid mass tending to burst the case by hydraulic pressure. The unit pressure at the diaphragm is the total pressure on it of 98,000 pounds divided by its area, and the strength of the walls to resist this fluid pressure is checked by the same formula as the powder chamber walls. In practice shrapnel are fired with excessive gun pressures into a sand butt and if the recovered case shows no marks of the rifling of the gun it is assumed that it is strong enough to stand the shock of firing.

To determine whether the case will stand the bursting charge a number of shrapnel are exploded by electric fuses in a steel-lined room, so that the cases may be recovered to see that they did not break up. Fig. 3 shows a special method of testing sample cases by hydraulic pressure and Fig. 4 shows a case tested by this method that failed, due to defective metal.

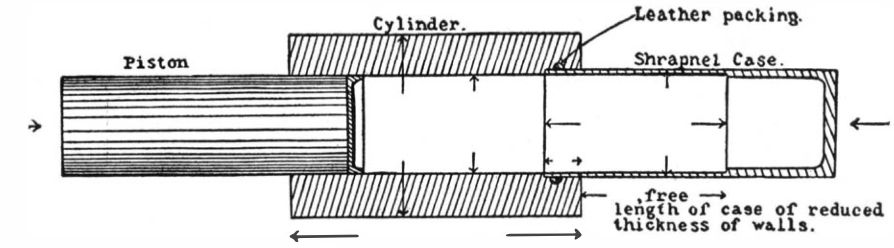


Fig. 3.—Bursting shrapnel cases by interior hydraulic pressure to detect hidden defects in the metal.

Great importance is attached to the velocity with which the balls are driven out of the case as this velocity is, of course, added to that of the projectile at the time of explosion. To determine this increased ball velocity a shrapnel is suspended in the air as shown by Fig. 5 and exploded by an electric fuse. Frames strung with electric wires leading to velocity measuring instruments are so arranged that not only the forward velocity of the balls but the rearward velocity of the case, which is used as a check on the total energy of the balls, are measured.

The "pattern" and angle or "cone" of dispersion of the balls when the projectile explodes in flight are determined by firing the shrapnel through a wooden screen to explode it and catching the fragments on a wooden frame perhaps 30 feet square covered with paper. Fig. 6 shows a typical "pattern." This test corresponds to that of a hunter who fires his shotgun against a fence to see about how far the shot spread and whether they are evenly distributed.

Fig. 7 shows the rapidity with which the ball velocity falls after the balls leave the case. A burst which will give about one ball to each square yard is considered desirable, and in the United States service it is assumed that the ball must have an energy of 58 foot pounds to put a man out of action, or a velocity of 400 feet per second with a 170-grain ball. If the velocity is high the point of burst can be such a distance in front of the target that the desired dispersion will be obtained, but if the velocity is low or the shrapnel is of large caliber containing a great number of balls, the theoretically correct point of burst will be so far in front of the target that the balls will arrive with insufficient energy to be effective.

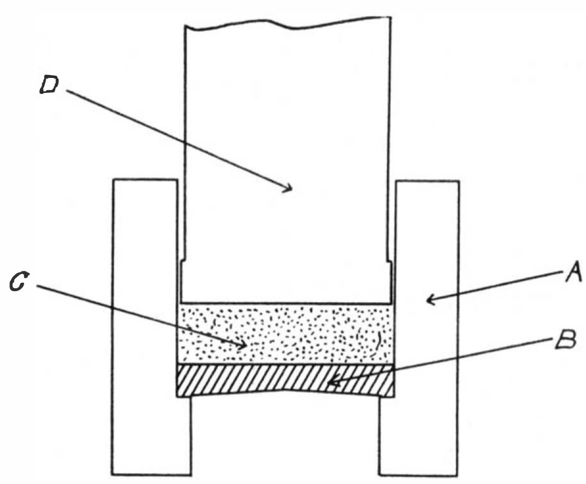


Fig. 2.—Fixture for testing shrapnel diaphragms.

A, steel cylinder; *B*, diaphragm; *C*, sand; *D*, steel punch pushed down by hydraulic press.

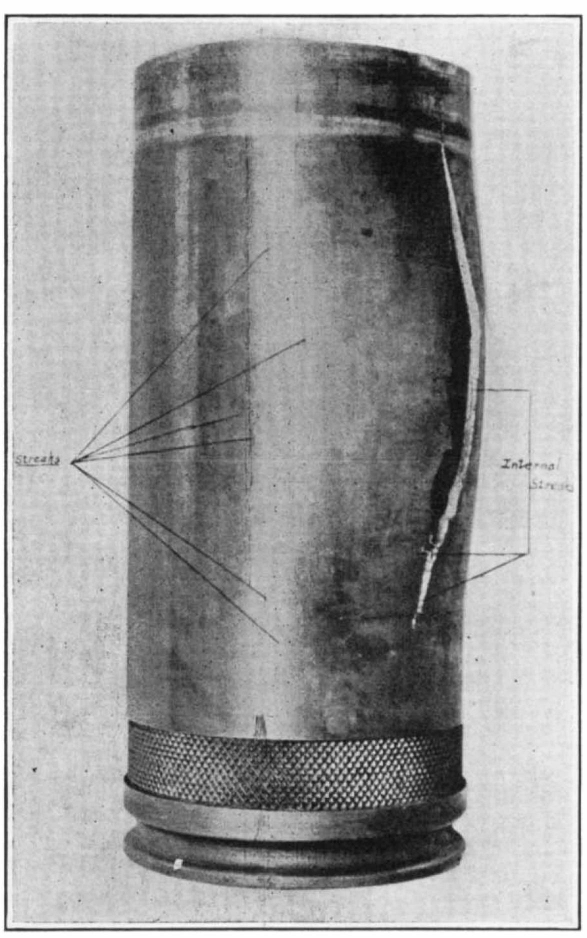


Fig. 4.—6 inch shrapnel case burst by the testing fixture shown in Fig. 3.

The fractures followed hidden streaks in the metal rather than the streaks on the exterior that probably threw the case under suspicion.

Proper remedies for this condition are to increase the size of the balls and reduce the number, to use a stronger case with a larger bursting charge, and if a new gun is also being designed to increase the twist of the rifling so that the angle of dispersion of the liberated balls will be greater, due to their greater centrifugal velocity.

Another modern expedient is to reduce the number of balls and put part of the weight into a relatively large head loaded with high explosive which continues on its way after the explosion of the shrapnel and explodes as a shell when it strikes the ground. An old method was to spread the balls by putting the bursting charge in the head and breaking up the case. This has, however, been completely discarded as all increased ball velocity due to the explosion is lost and the ball velocity may even be reduced below that of the projectile at explosion.

Wave or Vortex

RESEARCHES into the nature of air spirals or whirlpools, begun many years ago by a prominent French manufacturer, have recently been taken up by members of French and Russian learned societies, and have been the subject of a good deal of discussion, according to *Le Genie Civil* of April 8th.

The means of experiment employed have been the air currents generated by rapid rotation of cylindrical spindles, or spheres, and whose behavior has been revealed by their effects upon minute particles of gold-leaf and saw-dust, as well as upon jets of steam. A number of most interesting results have been obtained, which are taken as indicating a strong analogy between these air-whirls and the magnetic field.

Just as we have two kinds of electric induction, which result in the phenomena of attraction and repulsion, it is found that a rotating spindle generates two types of air-vortex, one traveling toward the equator of the spindle, the other toward the extremities. Moreover, two of these air-spirals which rotate in the same sense repel one another, and two which rotate in opposite senses attract one another; this attraction and repulsion being so strong that if the spindles are free to move longitudinally, the vortices will actually approach or recede from one another, carrying their generating spindles with them. The likeness or unlikeness of the air-spirals is regulated by rotating the spindles in the same or in opposite senses. And in every respect these air spirals are comparable to the magnetic lines of force.

It is suggested by the scientists who have investigated this matter, that the wave-theory of light, electricity, and similar phenomena, may have to be replaced by a spiral or vortex theory. They point out that under the wave theory it is difficult or impossible to explain the failure of material obstacles to interfere with the passage of the wireless current on any other ground than that electricity, like light, is susceptible of diffraction. But, they aver, the objections to the diffrangibility of the electric current, based on a comparison of the conditions of electric transmission with those of light transmission, are insurmountable. Hence they hope to see physicists driven to the vortex as a substitute for the wave-length.

Drainage to Prevent Erosion*

Benjamin Brooks

THE problem of soil conservation on a watershed is like the problem of flood prevention, navigation and power development on a river. To be properly solved it must be studied broadly from the source down. Much more popular interest and support and much better results have been obtained by handling river navigation, flood prevention and power development together than by handling them separately, for they are all three related. But erosion of watersheds is first cousin to them all, and should be included in the discussion of the family affairs. It should be put on the list of natural resources to be conserved, for upon it we chiefly depend for our three hundred million square meals a day.

United States Army engineers have spent a great deal of money dredging harbors, removing sand bars and setting beacons for the sake of navigation. The mud they dug was of no interest to them. Other engineers have spent other large sums in chaperoning unruly rivers across the map so that they could successfully carry their silt along to fill up the harbors again. To them the mud was merely a menace to fill up their channels during low stages of the river so as to cause it to seek new channels during freshets.

In 1840 the Chemung River in New York appeared to an engineer who was born upon its banks, and was then six years old, as a clear, smooth stream with well-defined channel and firm grassy banks. Fifty years after, at the time of a freshet, it was scarcely recognizable. The banks were twice as far apart, the river was full of bars and had forsaken its proper course to tear up the crops and the property of the unhappy citizens who lived beside it. This old inhabitant blamed the wood cutters for this, without measuring the stream to find that no more water was going by than in his childhood and without stopping to consider that accurate gagings for fifty years on American rivers and for eight hundred years on the Danube show no general increase in floods throughout the whole process of deforestation and civilization—that is, no general increase in the *amount* of water carried during floods, although the destructive effect of this amount has increased many fold. Why?

Very few of us engineers have followed this question properly to its source, nor regarded it as a sufficiently close relative to our other river questions, to solve it. One reason for this is that, as we approach the source of the difficulty, the problem frays out into countless separate little problems too small to interest the civil engineer or to pay him to solve. In fact, among older peoples, the solution is already well known. The chief difficulty in our new civilization is to get the old solutions applied. In the mountainous districts of the Philippine Islands, for instance, the savages (so called), although they have not yet discovered how to wear breeches, have developed a tremendous system of retaining walls and terraces so that entire flanks of the steepest mountains that would lie bare to the cloudburst and deluge in our states are brought under intensive cultivation despite a customary and frequent downpour of rain a day. In the Caucasus Mountains the inhabitants often use a similar system, and so well aware have they become of the value of soil that if any escapes them, they descend to the valleys and carry it painstakingly back again in baskets on their heads.

In the uplands of the Carolinas and Georgia the farmers have been in business in one place long enough to realize that the light top soil which floats away from them so easily is their principal stock in trade and must be conserved. I have ridden hours through this district, seeing scarcely a hillside that is not completely terraced—the steps being maintained by stiff, thick, low-cut hedges which are not interfered with during cultivation. In this same district the Mangum terrace was invented—a low mound approximately following the contour, able to retain soil and prevent stream flow, but still allowing the agricultural machinery to pass over it.

Coming now to a newer country near home, we can see the idea of soil conservation just beginning to take root. I have met and talked with some of the oldest farmer inhabitants along the south bank of the Missouri. Their farms lie in a hill country with very light soil some miles back from the main stream, but drained by small tributaries. These men have been through the whole gamut of experience, starting with smooth, grass-covered farms, plowing the grass under, loosening the soil and having it wash away from them, leaving only deep ragged gullies and mortgages; then having to devise their own means of retaining what soil was left and refilling the gullies with it.

To accomplish this they worked on two main principles of soil conservation, which they discovered slowly but by bitter experience. They found out what every civil engineer knows, that running water caught in the act of robbing a farm of its soil can be arrested in a pool long enough to drop its loot and go on *empty handed*. Their method of arresting it is simply to throw earth dams at intervals across the gullies; but, in order that the dams shall not be overflowed and washed out, they provided each with a by-pass, pipe underneath and a suitable riser made of ordinary clay sewer pipe, so that the water pooled and rose to the height of the by-pass, dropped its soil, and ran off comparatively clear. As the gully filled up with this deposited soil, they raised the dam and added more sewer pipe to the riser until the entire gully became a flight of smooth terraces instead of a hole in the ground.

The other principle they discovered is also well known to us—the fact that water, soaking slowly down through

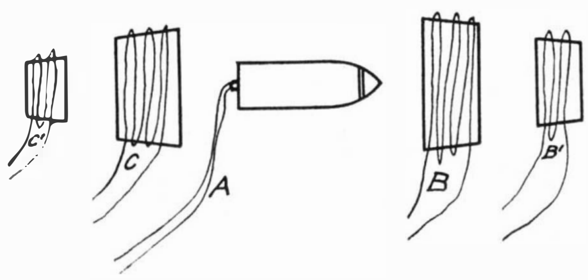


Fig. 5.—Measuring the velocity of shrapnel balls and case.

The suspended shrapnel is exploded by an electric fuse, current being supplied through the wires *A*. The expelled balls break the electric circuits *B B'* and the case circuits *C C'*. The screens of each pair of circuits are about 25 feet apart, and the interval of time taken to travel this distance is recorded by special instruments.

soil and out through sub-drains, will cause no erosion; while the same amount of water coursing over the surface will cause it. Accordingly, some of them laid clay drain tile along the bottoms of the gullies and filled in over them. Sometimes they combined the two ideas, throwing low dams across the filled gullies and connecting a riser pipe with the drain below. They went so

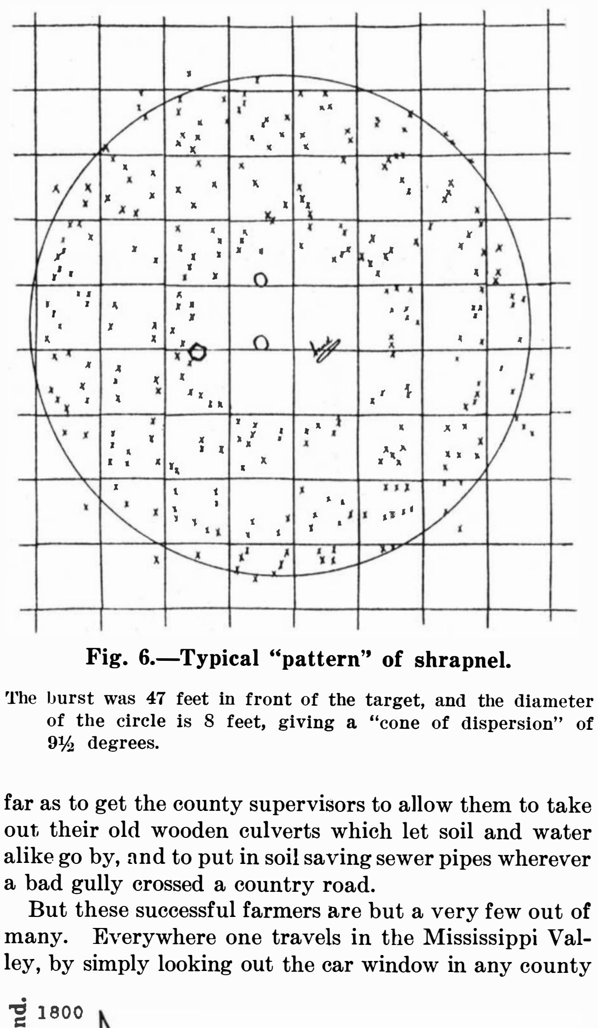


Fig. 6.—Typical "pattern" of shrapnel.

The burst was 47 feet in front of the target, and the diameter of the circle is 8 feet, giving a "cone of dispersion" of 9½ degrees.

far as to get the county supervisors to allow them to take out their old wooden culverts which let soil and water alike go by, and to put in soil saving sewer pipes wherever a bad gully crossed a country road.

But these successful farmers are but a very few out of many. Everywhere one travels in the Mississippi Valley, by simply looking out the car window in any county

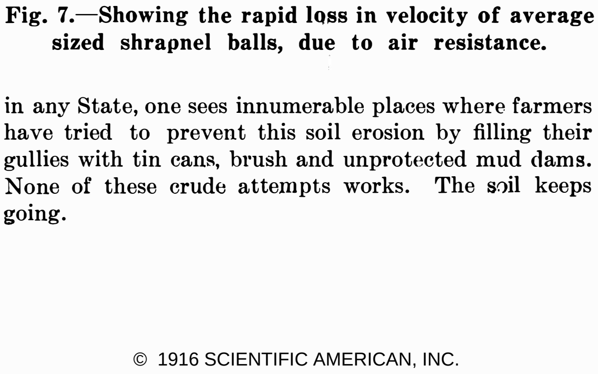


Fig. 7.—Showing the rapid loss in velocity of average sized shrapnel balls, due to air resistance.

in any State, one sees innumerable places where farmers have tried to prevent this soil erosion by filling their gullies with tin cans, brush and unprotected mud dams. None of these crude attempts works. The soil keeps going.

Now here is the important and most regrettable point. Although these petty details on the farm can never each receive the individual attention of a life-sized engineer, still it is exactly from these innumerable small beginnings that the ruination of the continent—already said to have spread over three million square miles—begins. These are the little sources from which rivers receive the silt that lessens their depth, increases their width, spills their floods over valuable property and shoals the harbors. The source of the soil is not the source of the main rivers. The Missouri, the Platte, the Arkansas, the Red River, are all comparatively clear streams near their sources, and receive their load of soil only when they reach plowed land. Old farmers have shown me tributary streams which used to be clear before they broke the soil, but which are now heavy with brown silt. I have old charts of San Francisco Bay and the testimony of old-time yachtsmen still living to show that certain towns near the confluence of the two principal rivers of the State were once on navigable waters although I have found it impossible to get within a mile of them in a boat drawing three feet. This change is coincident with the cultivation of the broad valleys above. When the Phoenicians first landed at the eastern end of the Mediterranean they founded their cities on isolated rocks off shore. When the Israelites came to cultivate and plow the adjacent slopes, these cities became part of the main land. Government reports, engineering reports, history and geography all contain copious proofs that agriculture is the chief factor in soil erosion, river clogging, flood increase and harbor shoaling.

But it will be a long time in this country before farmers generally will be driven by necessity to conserve their soil for its own sake. They will never do it for these other considerations of flood prevention and navigation. We engineers will never have time to devote to each farm piece-meal. The matter must be handled in a more wholesale, inter-related way; and the object of this paper is principally to suggest two or three ways.

The United States Government is already on the point of saying how much sewage a community may dump into a river on account of public health. Countless analyses have already been made along our principal streams in preparation for saying just this. Is it inconceivable that once having demonstrated to the right authorities where the soil comes from, the government, instead of appropriating millions of dollars to fix up temporarily a silt-clogged river, might take account of the silt content in a certain tributary stream and compel every farmer on its watershed to take such precaution against soil erosion as to prevent, or pay a fine for spoiling the public's navigable river? Or take it in connection with floods. We all know that tile draining is something more than a quick way of shedding water. It will take the farmers—generally speaking—a long, long time to think of it as a means of improving his soil, of emptying it of surplus water and filling it with air without drying it, to his great benefit. But if we are to regard tile drainage on a large scale throughout wet lands as a means of making the entire floor of the Mississippi Valley into a storage reservoir three or four feet deep which could have no surface torrents rushing over it, but which would deliver water to the rivers at, say, half an inch each twenty-four hours, then the flood prevention commissioners might take notice and ultimately find a way to penalize a man who neglectfully stored a potential flood on his land. By such a stroke all three difficulties—soil erosion, navigation interruption, and floods—could be overcome at once and on a large scale compatible with modern engineering.

Or take it again on the principle of public sanitation. While our American health boards and investigators have been studying various bugs, flies, germs and fungi to discover which is the cause of Pellagra—that European scourge that is gaining so rapidly in this country—the University of Rome, after years of continual research, has definitely determined and proved that Pellagra is caused by muddy water—by the erosion of agricultural soils containing colloidal silica. In New Hampshire, Nevada, Utah, Wyoming, and Minnesota (districts free from clay waters) there is no Pellagra. In the Carolinas, in Georgia, Missouri, Illinois (places where the farmer turns the streams a rich chocolate color) there is an ever-increasing and seriously menacing amount of it. To prevent soil erosion would eliminate one more hitherto invincible enemy of mankind.

The American farmer, no matter how little he reads or how heedless he may be of our individual suggestions, will finally come, through dire necessity, to the idea of conserving his soil just as the naked farmer of the Philippines has finally left off hunting the heads of his wife's relatives and taken to giant powder, rock drills, stone walls and terraces; but if our influential engineering societies can suggest strongly enough to our influential law-makers how the important problem of soil saving may be connected to and handled with our other great national engineering problems, we may save a few generations of time and a great part of the arable continent.

*The *Iowa Engineer*.

The Cosmological Ideas of the Greeks*

Philosophy Which Aimed to Comprehend the World in a Natural Way

Hector MacPherson, M.A., F.R.A.S.

(I) THE SPECULATIVE PERIOD.

To THE ancient Greeks belongs the honor of separating, for the first time, cosmology from theology. Just as the genius of the Hebrew people was religious, that of the Hellenes was in the direction of philosophy and art. And just as the Hebrews developed the religious view of the world, it fell to the Greeks to develop the philosophic view. As Eucken remarks: "Philosophy which, in the case of the Greeks, does not start from man and the problem of his happiness but from the Universe as a whole, aims to comprehend the world in a natural way by means of its own interconnections; it seeks for an immutable substance or for fixed quantitative relations. It is forced to discard the first impression of things and to destroy their visible image; but with a sure instinct for the essential it reconstructs the world in outlines whose simplicity bears the marks of genius and excites our perpetual wonder."

Nevertheless Greek cosmological speculation had its origin in the mythological age, and was at first similar to the mythologies of Babylon and other ancient lands. In the poems of Homer and Hesiod we meet with earlier Greek cosmological ideas; and in them cosmology and theology are, as in the Babylonian world-concept, inextricably connected.

Both Homer and Hesiod, in their poems, give us an idea of the world-view of the primitive Greeks. In Homer, the earth is a flat circular disk, surrounded on all sides by the great river Okeanos. This mighty river commenced north of the Pillars of Heracles, and wound its way north, east and south of the earth. The disk of the earth is supposed to be partly covered with the sea. Southwest of the river Okeanos is the land of the Cimmerians; and, in some places, Homer indicates that adjacent to the Cimmerian land is Erebus or the land of the shades; in other passages, however, Homer places Hades beneath the surface of the earth.

Above the earth is the region of the ether; and still higher is the vault of the heaven. Beneath this vault the sun, moon and stars perform their motions, rising out of Okeanos in the morning and returning thither at night. The Hesiodic conception is somewhat similar. Hesiod places Tartarus, "the depth," as far below the earth as the height of heaven is above. Thus, the whole universe is represented as a sphere. And this sphere is divided into two halves by the earth's surface. This conception is somewhat akin to that of the Hebrews, as brought out by Schiaparelli. In his "Theogony" Hesiod puts forth his cosmogonic views. How far this work is the product of purely Hellenic thought is uncertain. Pfleiderer considers that the work "in many instances disarranged popular legends with foreign Asiatic speculation." In the beginning was Chaos, from which sprang the earth-goddess Gaia, the mother of all. Then follow Erebus and Aether, and these are followed by the production of Uranos, the god of the heaven, and from the union of the god of heaven and Gaia, the goddess of earth, there springs the race of gods and titans—personifications for the most part of natural forces. The only important point about the theogony is the fact that the earth sprang from Chaos, and from the union of Earth and Heaven the other personified natural forces were produced.

What Hesiod actually meant by Chaos is uncertain. Plutarch believed it to be water; and in one or two places, Homer speaks of Okeanos as the origin of everything. Here we have the connection of Greek and Babylonian mythology, as Dr. Dreyer notes, "the connecting link between the primitive popular notions and the first attempt at philosophical enquiry."

This first attempt was due to Thales of Miletus, the first Greek philosopher. It is true that his idea of the constitution of the world was as primitive and, in the light of later knowledge, as absurd as those of Homer and Hesiod. The earth, he believed, was a circular disk floating like a piece of wood on the ocean; and in water Thales found the ultimate principles or substance of the world. At first sight Thales may appear to have advanced but little beyond the standpoint of the poets; but there is one essential difference between his explanation of the world and theirs. Thales separated cosmological from religious speculation. In his explanation of the universe there was no mythological element. No gods or goddesses were invoked—as in the cosmology of Hesiod and in the creation epic of the Babylonians. Aristotle discussing Thales' belief in water as the "first principle" suggests that the Milesian philosopher got the idea "because he saw that the nourishment of all beings is moist and that heat itself is generated from moisture, and persists in it (for that from which all things spring is the first principle of them) and getting this idea also from the fact that the germs of all beings are of a moist nature." Thales, at all events, has the distinction of being the first scientific philosopher.

Anaximander, the second philosopher of the Ionian school, abandoned the view of Thales. He found the first principle not in water nor in any other substance, but in the infinite (το 'απεἰρον) or the indefinite. This, says Schwegel, "was not something immaterial, but was probably conceived by Anaximander as primal matter not yet sundered into its individual elements." Out of this are all things developed and into it all things return. This conception of the origin of things was a remarkable one, and the sagacity of Anaximander's cosmogony is a strange contrast to the crudity of his world-view. He believed the earth to be flat or convex on the surface and to be in equilibrium in the center of the world. The heavens, he considered, were of the nature of fire and spherical in form. The heavenly bodies were thought to be placed at different distances—the sun being more distant than the fixed stars. He had a curious explanation of the nature of the heavenly bodies. The sun was a hole in a great ring through which the inhabitants of the earth got a view of the fire which filled the rim of the ring, while the moon and stars were similarly explained.

Anaximenes, the third of the Ionian philosophers, was, if anything, less advanced than the second. He found the "first principle" in air out of which all things were formed by compression or rarefaction; thus the earth was produced from dense air. Anaximenes believed the earth to be flat and the sun, moon and planets to be also flat bodies, while he supposed the stars to be attached like nails to a solid vault.

The Ionian school did not advance very far in the explanation of the world. At the other end of the Greek world, however, another school of thinkers—the Eleatics—had arisen and they developed more advanced views. Xenophanes, the founder of the school, it is true, did not advance beyond the Ionion standpoint. The earth he believed to be flat and "rooted in the infinite," while the sun, comets and stars were supposed to be fiery clouds. The sun and stars were formed daily from fiery particles while the moon was a compressed cloud which shone by inherent light and was extinguished monthly. Parmenides, the virtual founder of the Eleatic school, was a much more profound thinker. To him belongs the distinction of perceiving the spherical form of the earth—a great advance in thought; he considered the entire universe to consist of a number of concentric layers encircling the stationary earth. This is the first time, as Dr. Dyers observes, that we meet with the conception of concentric spheres. Parmenides also noticed that the moon appears "always gazing earnestly toward the rays of the sun" and he drew the correct deduction that it shines by reflected light. He considered the sun and moon to consist of materials detached from the "Milky Way," and the stars to be nearer to the earth than the sun, an error similar to that of Anaximander.

Curiously enough Heracleitus of Ephesus, who was a thinker at least as profound as Parmenides, was much less happy in his cosmological speculations. Heracleitus found the explanation of the world in univsersal flux—"Becoming," "All things flow" (πανιᾶ ρει). Accordingly he was led to consider fire to be the "first principle" of the world. There is, he taught, an unending circulation in nature "upward, downward, the way is one and the same." Accordingly it was in keeping with the doctrine of flux to revert to the idea of a flat earth. The sun he believed to be formed of moist exhalations caught in a hollow basin with its cavity facing the earth. The orb of day was ignited every morning and extinguished every night. On the whole Heracleitus' cosmological speculations marked not an advance but a retrogression in thought. Indeed the marvelous intuition of Parmenides seems to have been completely overlooked. Such illustrious thinkers as Anaxagoras, Empedocles, Leucippus and Democritus erred fundamentally in regard to the shape of the earth.

Anaxagoras believed that mind (νους) had produced the world out of the original chaos—the most profound idea of the ultimate cause of the universe put forward before Plato and Aristotle. Mind formed the world by starting a rotatory movement, by which the present state of things was produced. Matter was thus separated into two halves, ether and air. The air—cold, dark, and heavy—was agglomerated in the center, and from this was produced water from which again earth appeared. The earth was considered to be flat, and the sun and moon were supposed to be composed of similar matter—a considerable advance in thought. Anaxagoras also held the somewhat absurd view that the Milky Way represented the shadow of the earth.

Empedocles—working from his idea of four primary elements, fire, air, water and earth, swayed to and fro by love and hate, attraction and repulsion—believed the universe to be spherical and the earth to be flat. The moon he considered to be air rolled together and mixed with fire and illuminated by the rays of the sun, which was itself "a reflection of the fire surrounding the earth."

Leucippus and Democritus were the first exponents, in rudimentary fashion no doubt, of scientific materialism. Leucippus believed matter to consist of an infinite number of atoms, very small and indivisible, by the union and separation of which the world is caused. Democritus believed that as a result of collisions among the atoms themselves a vortex motion resulted. Thus an infinite number of worlds is formed and thus the earth originated. The earth, according to Leucippus, is flat on the surface with an elevated rim. Democritus considered the earth on the other hand to be a *discus*, higher at the circumference and lower in the middle. The sun and moon were considered to be large and solid masses. In regard to the moon and to the Milky Way, Democritus held views in advance of his time. He believed the lunar markings to be due to the shadows of mountains and valleys; and he propounded the view that the Milky Way was an appearance due to the combined light of many faint stars.

More influential than the Ionian or the Eleatic schools or than the followers of Heracleitus and Democritus was the famous Pythagorean Brotherhood. The philosophical school of Pythagoras was not only devoted to science and philosophy; it was also a religious society and a political organization. Hence it occupies a somewhat unique place in the history of Greek thought.

The underlying idea of Pythagoras was that the explanation of everything is to be sought in number. In the clear words of Dr. Dreyer, Pythagoras believed that "number not merely represents the relations of the phenomena to each other but is the substance of things, the cause of every phenomenon of nature. Pythagoras and his followers were led to this assumption by perceiving how everything in nature is governed by numerical relations, how the celestial motions are performed with regularity and how the harmony of musical sounds depends on regular intervals the numerical valuation of which they were the first to determine." Amid a great deal of fantastic speculation, Pythagoras seems to have got hold of various aspects of truth. To him, the universe was a sphere; and at its center was the earth, also of a spherical figure. This view, held by Parmenides alone outside of the Pythagorean School, was now accepted by the disciples of the founder.

The Pythagoreans latterly advanced beyond their master's cosmological standpoint. Philolaus taught that the apparent rotation of the starry sphere and the motion of the sun around the earth are caused by the movement of the earth in twenty-four hours round the circumference of a circle. This idea, incorrect though it was, marks a real advance in scientific thought. Philolaus went a step further. He considered that the earth could not be the center of the universe, but that the earth and the other celestial bodies moved round the "Central Fire" or the "Hearth of the universe." This body Philolaus and his followers held to be invisible from Greece and only to be seen in the regions beyond India. This doctrine called forth the ridicule of Aristotle. "They forcibly make," he said, "the phenomena fit their opinions and preconceived notions and attempt to construct the universe."

In many ways the Pythagoreans deserved the ridicule of the great philosopher. For instance, as ten was supposed to be a perfect number, it was necessary to assume the existence of ten celestial bodies. Only nine were known—the earth, the sun, the moon, the five planets, and the sphere of the fixed stars. Therefore the Pythagoreans imagined the existence of another body—the "antichthon" or "counter-earth" perpetually invisible from the inhabited side of our planet's surface.

Yet with all their errors the Pythagorean School under Philolaus took a remarkable step. They boldly declared that the chief place in the universe was not occupied by our world. Hicetas of Syracuse seems to have gone still further and anticipated partially the Copernican system. Cicero writing long afterward said that "Hicetas of Syracuse, according to Theophrastus, believes that the heavens, the sun, moon, stars and all heavenly bodies, are standing still and that nothing in the universe is moving

*From *Popular Astronomy*.

except the earth, which while it turns and twists itself with the greatest velocity round its axis, produces all the same phenomena as if the heavens were moved and the earth were standing still." Opposition was developed within the Pythagorean School not only to this notion but also to that of Philolaus. Both Philolaus and Hicetas were in advance of their time, and their views were destined to meet with but little approval.

In one particular the Pythagorean School did not teach in vain. The doctrine of the spherical form of the earth was never again seriously challenged by intelligent men. The Pythagorean School had in itself a wide influence, but it exerted a still wider influence through the greatest of ancient philosophers, and one of the greatest minds of all ages—Plato. On the whole, Plato had little interest in natural science. He had inherited from his master Socrates his somewhat contemptuous attitude to the observational study of nature. According to Xenophon, Socrates considered a knowledge of astronomy useful in so far as it enabled determinations of the days and hours to be made; but such questions as the orbits and distances of planets and stars and the causes of their revolutions, he considered to be a waste of time. Plato, like his master Socrates, was neither an astronomer nor a mathematician nor a physicist. Nevertheless he was destined on account of his far-reaching influence to have a profound effect on cosmological thought. In the *Timaeus*, Plato explains that the Deity made the universe and that he made it of a spherical shape, with one motion, that of rotation on its axis. After his exposition of his ideas regarding the "soul of the universe," Plato explains that God resolved to form a movable image of eternity on the principle of numbers, which is time. "With this design the Deity created the sun, moon and the five other stars, which are called planets, to fix and maintain the numbers of time." A good deal of controversy has raged over certain obscure passages. Some scholars consider that Plato believed in the rotation of the earth about its axis, and that he was actually a follower of Philolaus. But, on the whole, the balance of evidence is against the contention that he held such views. There seems no reason to doubt that he believed the earth to be the center of the universe, a sphere suspended in space, fixed and immovable at the center of creation.

In regard to the heavenly bodies, Plato considered that the stars, chiefly formed of fire, move through the ether, a particularly pure form of air, which reaches from the limit of the terrestrial atmosphere into the starry spaces. The moon he believed to be the nearest body to the earth; and in virtue of its proximity it resembled the earth more than did the other celestial bodies. He believed it to be dark, shining by reflected sunlight.

On the whole, it must be admitted that, great thinker though Plato undoubtedly was, stupendous as was his intellect, he played a very unimportant part in the history of cosmological thought. At the same time, there is no doubt that Plato did a great deal to popularize the notion of the spherical form of the earth. His books had a wide circulation in the ancient world, and his opinion carried extraordinary weight. By the time of Plato's death, therefore, the fact of spherical form was accepted on all hands.

(II) THE PRACTICAL PERIOD.

With Eudoxus of Cnidus, the cosmology of the Greeks entered on a new phase. With all his limitations, Eudoxus may be described as the first investigator of cosmological problems from a purely scientific standpoint. The changed outlook may be realized when we compare the methods of the previous thinkers with that of Eudoxus. The earlier philosophers had proceeded on the grounds of reason alone. Their method was deductive. Eudoxus, on the other hand, was on the whole an inductive thinker. He was an observer of the phenomena of the heavens and to explain these phenomena he advanced his famous theory of the homocentric spheres. Whether the theory was ever more to him than a convenient working hypothesis is uncertain. Dr. Dreyer, who has made a close study of the Eudoxian theory, believes that Eudoxus only regarded his spheres as "geometrical constructions suitable for computing the apparent paths of the planets."

The system was a very complicated one, but a brief sketch will suffice to explain its general nature. The earth of course was believed to be spherical, occupying the center of the universe, and each celestial body was believed to be situated on the equator of a sphere revolving with uniform velocity around its poles. But Eudoxus, by observation of the heavens, was aware of the irregularities—retrogressions, variable velocities and stationary points—of the planets, and so it was necessary to postulate the existence of other spheres. The poles of each planetary sphere were believed to be attached to larger spheres, concentric with the others rotating round different poles with varying velocities. These poles of the second spheres were themselves rotating round other and still larger spheres. For the sun and moon Eudoxus found three spheres each sufficient, but in order to explain the complicated motions of the planets it was necessary to assume the existence of four spheres for each. For the fixed stars, of course, one sphere was sufficient. Finally Eudoxus had to assume the existence of twenty-seven spheres in all. On the whole, the theory, complicated and cumbersome though it was, accounted fairly well for the observed celestial motions. It explained the motions of all the planets, except Venus and Mars, but this is not to be wondered at, considering the insufficient observational data on which Eudoxus was compelled to work. Thirty years after the theory was first propounded, it was improved by Calippus, a pupil of Eudoxus, who is also known for his improvement on the Metonic cycle. Calippus considerably altered the system by adding a number of extra spheres to explain irregularities which had either escaped the notice of Eudoxus or which had been ignored.

The theory of homocentric spheres, as it is generally called, seems cumbersome if not fantastic in the light of present-day knowledge, but viewed in its true light it marks an era in cosmological speculation. It was the first attempt to account for the observed phenomena of the universe. Eudoxus was not a philosopher; he was first and foremost a mathematician and man of science, and his theory was framed to explain observed facts. Indeed, as already mentioned, to him it may have been a convenient working hypothesis and nothing more.

If the theory was merely a theory to both Eudoxus and Calippus, it was a great deal more to Aristotle. In fact, it formed the basis of that great philosopher's cosmological conceptions, which exercised so profound an influence over human thought not only in his own day but throughout the post-classical period and the Middle Ages. When we realize the range of Aristotle's researches and his deservedly great reputation as philosopher and moralist, we are enabled to understand, partly at least, the reason of his long supremacy over the minds of men.

The natural philosophy of Aristotle was expounded in the eight books of his work on "Physics," in his four books on "The Heavens," and his four books on "Meteorologica." In the first of his books on "The Heavens" he argues that the material universe cannot be extended indefinitely in space, since a line drawn from the center of our earth to a body indefinitely distant could not perform a motion of rotation in twenty-four hours. If the Aristotelian universe was not infinite, however, it was regarded as eternal. In his cosmical speculations Aristotle was largely guided by his philosophical ideas. He adopted the view of Eudoxus as to the spherical shape of the universe. On the ground that the sphere is among bodies the most perfect. In the spherical cosmos the most perfect sphere is that with the most perfect motion; and as the swiftest sphere is the most perfect in motion, the outermost is the most perfect of all. The entire argument is purely speculative and the outlook of Aristotle on the ultimate problem of the universe contrasts strangely with the scientific procedure of Eudoxus, whose cosmological hypothesis he adopted. To Aristotle the spheres were actually in existence, portions of the vast mechanism of the universe. He found it necessary—in order to explain why the motion of the outer spheres was not shared by the inner in spite of their connection—to add twenty-two extra spheres. Calippus had assumed the existence of thirty-five, so that as left by Aristotle, the system comprised fifty-two separate spheres.

Aristotle devoted considerable attention to the form of the earth, its position in the universe, and its possible motion. Aristotle bases his belief in the spherical shape of the earth on both theoretical and empirical considerations. The former are of little account, but the latter are of more permanent value. He notes first the fact that the shadow thrown by the earth on the moon is always circular, showing that the earth must be a sphere; and second, a journey north or south changes the apparent positions of the stars. He mentions the Pythagorean view that not the earth but a central fire occupies the center of the universe, but this theory he rejects in favor of the view that the earth is fixed and immovable in the center of creation; and he does not seem to have been acquainted with the view of a rotation of the earth on its axis.

Aristotle is careful to distinguish between the heavens, the region of unchangeable order where circular motion prevails, and the region below the lunar sphere in which are placed the four elements, earth, water, air and fire. The ether he believes to become increasingly pure at greater distances from the earth's surface; and in the upper atmosphere comets and meteors and auroræ were believed to be produced. He also believed the Milky Way to be an atmospheric phenomenon.

After all the cosmological ideas of Aristotle do not seem to be very far in advance of those of earlier thinkers; and indeed in some instances his opinions were decidedly reactionary. There is therefore a natural temptation to ask why the opinions of Aristotle on cosmology should have so great weight in later years. The answer is to be found in the unique position occupied by Aristotle in the history of thought. He was not merely an astronomical or scientific thinker, or a great mathematician. He was the most commanding figure of his age and in him, so to speak, was summed up the scientific and philosophic culture of the Hellenic world. Thus the pronouncements of Aristotle, even in the Hellenistic period, were invested with peculiar authority.

We find, for instance, that among men of philosophic or scientific mind, the spherical form of the earth was never again seriously disputed; while the erroneous doctrine of the fixity of the world in the center of the creation was invested with all the authority of the greatest of philosophers.

Yet, almost contemporary with Aristotle, there were two distinguished Greeks who seem to have grasped the truth in regard to the earth's place in nature. Heracleides of Pontus was a pupil of Aristotle, but appears to have had the courage to think for himself on the system of the world. In the words of the commentator Simplicius "Heracleides of Pontus, assuming the earth to be in the middle and to move in a circle, but the heavens to be at rest, considered the phenomena to be accounted for." Aetius, another ancient writer, remarks that Heracleides considered the earth to move "not progressively, but in a turning manner, like a wheel fitted with an axis, from west to east, round its own center." In other words, Heracleides believed that the earth turned on its axis in twenty-four hours and thus explained the apparent motion of the sphere of the fixed stars. Another forward step was taken by Aristarchus of Samos, who boldly declared that instead of the sun moving round the earth, our world traveled round the sun. "He supposes," said his contemporary Archimedes, "that the fixed stars and the sun are immovable but that the earth is carried round the sun in a circle." His brilliant intuition, however, was destined to obscurity. It did not harmonize with the opinions of Aristotle and the authority of the great philosopher was supreme. Besides, even in those Pagan days, the heliocentric theory was considered a dangerous doctrine. According to Plutarch, "Cleanthes held that Aristarchus of Samos ought to be accused of impiety for moving the hearth of the world, as the man, in order to save the phenomena, supposed that the heavens stand still and the earth moves in an oblique circle at the same time as it turns round its axis." Aristarchus was the last thinker of the Greek world who strove to find the physically true system of the universe. The theories which followed were merely mathematical hypotheses representing the motions—regular and irregular—of the various planets.

It is somewhat remarkable that while more and more stress was laid on Aristotle's opinion as to the immobility of the earth, the astronomical theory on which he based his hypothesis—the spheres of Eudoxus—was soon discarded. The rise of practical astronomy by demonstrating its inadequacy hastened its rejection. The necessity of regulating time, the need for an accurate calendar, had stimulated observation of the sun and moon and this in turn influenced other branches of astronomy. At Alexandria, under the patronage of the dynasty of the Ptolemies a school of astronomy was founded and systematic observation of the heavenly bodies was made. As Dr. Dreyer has well remarked, "Vague doctrines and generalizations were abandoned, while mathematical reasoning founded on observation took their place. That this change occurred about the middle of the third century was a circumstance not unconnected with the simultaneous rise of the school of Stoic philosophy. Both in abstract philosophy and in science the wish to get on more solid ground now became universal and no science benefited more by this realistic tendency than astronomy."

To Apollonius of Perge is due the distinction of inventing the famous theory of epicycles which superseded the spheres of Eudoxus. After using for some time the so-called theory of "excentric circles," Apollonius put forward the theory of epicyclic motion. The idea of concentric spheres was abandoned; sun, moon and stars were assumed to be in motion round the earth in circular orbits; but some explanation had to be given of the irregularities of the celestial motions. In essence, the systems of Apollonius, Hipparchus and Ptolemy were identical, but the latter scientist worked the epicyclic theory to its fullest perfection.

The epicyclic theory is not easy of explanation and we cannot do better than reproduce the exposition given by Sir Robert Ball in his sketch of Ptolemy. He takes the typical case of Mars with its irregular motion. "We have the earth at the center and the sun describing its circular orbit around that center. The path of Mars is taken as exterior to that of the sun. We are to suppose that at a point M there is a fictitious planet which revolves around the earth uniformly in a circle called the deferent. This point (M) which is thus animated by a perfect movement is the center of a circle which is carried onward with M and around the circumference of which Mars revolves uniformly. It is easy to show that the combined effect of these two perfect movements is to produce exactly that displacement of Mars which observation discloses."

This is a sketch of the theory at its simplest, but it is

sufficient to illustrate its general principle. As astronomical observation progressed, new irregularities were discovered and had to be accounted for. Hipparchus of Rhodes will ever hold the chief place among the astronomers of antiquity. Not only did he form a catalogue of stars, and thus lay the foundations of practical astronomy, not only did he discover the precession of the equinoxes, but he succeeded in working out solar and lunar theories. He did not satisfactorily explain the motions of the planets on the epicyclic theory, and in fact he merely accepted the epicyclic theory, as a convenient working hypothesis.

In Ptolemy of Alexandria, who lived three hundred years after Hipparchus, ancient science reached its culmination. In his great work the "Syntaxis," commonly known as the "Almagest," he develops the theory to its fullest extent. In the first book of his great work, he demonstrates that the earth is a sphere fixed and immovable in the center of creation, and the heavens is also a sphere, rotating in twenty-four hours round an axis. This is the fundamental assumption of the Aristotelian philosophy and Ptolemy accepted it. He worked out carefully the epicyclic theory in the light of the discovery of new irregularities in the celestial motions, and as a result a number of extra circles and epicycles had to be introduced.

Like Eudoxus and Calippus, Apollonius and Hipparchus, Ptolemy does not seem to have troubled as to the actual physical truth of his system. "I do not," he said, "profess to be able to account for all the motions at the same time; but I shall show that each by itself is well explained by its proper hypothesis." If to Ptolemy the theory was merely a working hypothesis, it was soon regarded by the intellectual world at large as the true system of the world. The philosophy of Aristotle and the science of Hipparchus and Ptolemy was the last word of ancient cosmological thought; and during the Middle Ages the word of these masters was final.

In the Hellenistic period—after Aristotle and Plato—men do not seem to have troubled over purely cosmogonic problems. There was little speculation as to how the world came to be. The Stoic School in so far as it concerned itself over such matters followed Aristotle. The pantheistic nature of the Stoic philosophy led these thinkers to the doctrine of an all-pervading primary substance co-extensive with matter. This primary substance identified by Cleanthes with fire, was generally regarded as one with the Deity. Thus the Stoic cosmogony resulted in pantheism.

The atomist school, represented among post-Socratic thinkers by the Epicureans, found its leading exponent in the Roman poet Lucretius. On the whole, Lucretius is not original; he merely reproduces the ruling ideas of Leucippus and Democritus. He pictures the concourse of atoms in indescribable confusion at the beginning of time. "At last the parts began to fly asunder, and like to join to like and mark off the members of the world and every one of its mighty parts—to separate high heaven from earth and let the sea spread itself out apart, and also let the fires of the ether spread apart, pure and unmixed." We cannot but be impressed with the retrogression illustrated by the cosmological fancies of Lucretius; and thus, he counts for little in the history of cosmology.

Hellenic culture had exhausted itself at the beginning of the Christian Era; and although it lingered on for some centuries, it counted for little in the world's thought. When the Emperor Justinian suppressed the Neoplatonist Schools in 529 he merely gave legal expression to an accomplished fact. The long night of the Middle Ages had begun.

Fundamentals of Signaling

Some confusion exists in the minds of employees not connected with the signal department, and possibly also in the minds of some signalmen whose experience has been confined to one railroad, perhaps to one division, as to just what the differences are in the several systems of signaling and interlocking. It is the endeavor in the following, to make these fundamentals clear, as well as to distinguish clearly between block signaling and interlocking, two subjects which are often confused in the minds of those not connected with the signal department.

Signaling is the control of railway operation by means of fixed signals. By fixed signals are meant those located permanently at given points, as contrasted with hand or other signals which are not restricted to any particular points on the road.

The purpose of signaling is to safeguard the movements of trains and to facilitate traffic. The method which is best adapted for a given location depends upon the amount and kind of traffic, climate and many other conditions. The fundamental systems will be described later in this series of articles.

There are two grand divisions of signaling: (1) block signaling, and (2) interlocking. Block signaling pertains to spacing trains moving in the same or in opposite directions on the same track. Interlocking is the means for routing trains over conflicting routes, as at crossings, junctions and terminals; or over routes that are not always intact or lined up for trains, as draw bridges, etc. The standard code definition for interlocking is: "An arrangement of switch, lock and signal appliances so inter-connected that their movements must succeed each other in a predetermined order." This refers to locking, that is, a switch or derail must be locked in its correct position before the signal is unlockel so that it can be cleared. Then, if the enginemen always obey the signals, it will be impossible for a train to be derailed or sent over a route not intended, when these are lined up for the train movements. The leverman is prevented from throwing switches and lining up two conflicting routes by the cross-locking in the interlocking machine.

Block signaling may be separated into two subheads: (1) the time interval system, (2) the space interval system. The time interval system is the old telegraphic block system; all that was attempted was to prevent a following train from starting out of a station until after a period of time had elapsed, or to prevent a train from leaving a station when an opposing train had already left the adjacent station in advance. The old telegraphic block was not a block system in the strict sense of the word.

The space interval system may be further subdivided into (a) manual block, (b) controlled manual block and (c) automatic block. And the order in which these systems are shown is the order in which they were developed in practice. The old telegraphic block was the first system used, following which was developed the manual block in which each signal is operated by a man located at the block station. Later, a further feature was added to the manual blocks, so that the actions of the operator were partially controlled in that the operator at the adjacent block station had to co-operate before the signals could be cleared.

In the automatic block system signals are operated not by the leverman, but by mechanisms which are controlled by the trains themselves, thereby eliminating the human element as far as the operation of the signals is concerned.

The time interval, or old telegraphic block system, requires no further explanation than that given above. In the manual block system, the block signals at a station are moved by a lever, operated by an attendant. By means of the telegraph or telephone, the attendant is instructed whether to clear his signal or to leave it at stop.

There are three variations of the controlled manual block system: (1) The lock-and-block system, in which the lever at a station is electrically locked by the lever of an adjoining station; thus the signal cannot be cleared to admit a train into the block without the consent of the signalman at the block in advance. (2) The controlled manual block with track circuits; with this system, if the operator at an adjoining block station makes a mistake and tries to clear up a route when it is occupied, the train itself prevents him, by means of the track circuit and a lock which locks the lever electrically. (3) The staff system, in which the rules require the engineman to have a staff before he has the right of way over the block section. This staff must be obtained from a machine which is electrically locked with the machine in advance. Two adjacent machines are so arranged that when the staff is withdrawn from one of them, the staff is locked in the opposing machine and cannot be withdrawn; thus, when an engineman tries to obtain the staff from a machine and enter a block which is already occupied, he will find the staff locked so that he cannot withdraw it. It is customary for operators to secure staffs from instruments and hand them to the engineman.

In the automatic block system, the signals are worked entirely by mechanisms which, in turn, are controlled by a train or by certain conditions affecting the use of a block, such as a misplaced switch, broken rail, etc. The basis of all systems of automatic block is track circuit control. The track is divided up into a series of insulated sections called track circuits, with one or more sections between each two adjacent signals. In each section there is a track circuit—current flows from a track battery located at one end of a section, to one rail, then through the rail to the opposite end of the insulated section, across to the opposite rail through an instrument called a relay, and then back again to the battery. The track circuit current energizes the relay which causes the signal to operate by closing a local battery circuit at the signal. There is a complete electric circuit and a continuous electric current in the track rails, then, when the track is unoccupied. When the track is occupied by a train, the electric current, instead of passing through the relay, the instrument which controls the signals, will be short-circuited and pass through the wheels and axles of the train and back to the battery without going through the relay. Depriving the relay of current causes the blade of the block signal to operate to the stop position by gravity. Thus, when the track is occupied by a train, the signal will come to a stop. When the track is again unoccupied, the original circuit through the relay will again be completed and the signal will be operated to the "clear" or proceed position.

This principle is what is called the "closed circuit." In case any part of the apparatus fails, a switch is not lined up correctly or a rail breaks, the current through the rails and relay will be cut off and the signal will operate to the stop position the same as if the track were occupied by a train. The signal indicating stop, with no train in the block, indicates to the signalman that something is wrong with the apparatus, and tests and repairs are made.—*Kenneth L. Van Auken in the Railway Review.*

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