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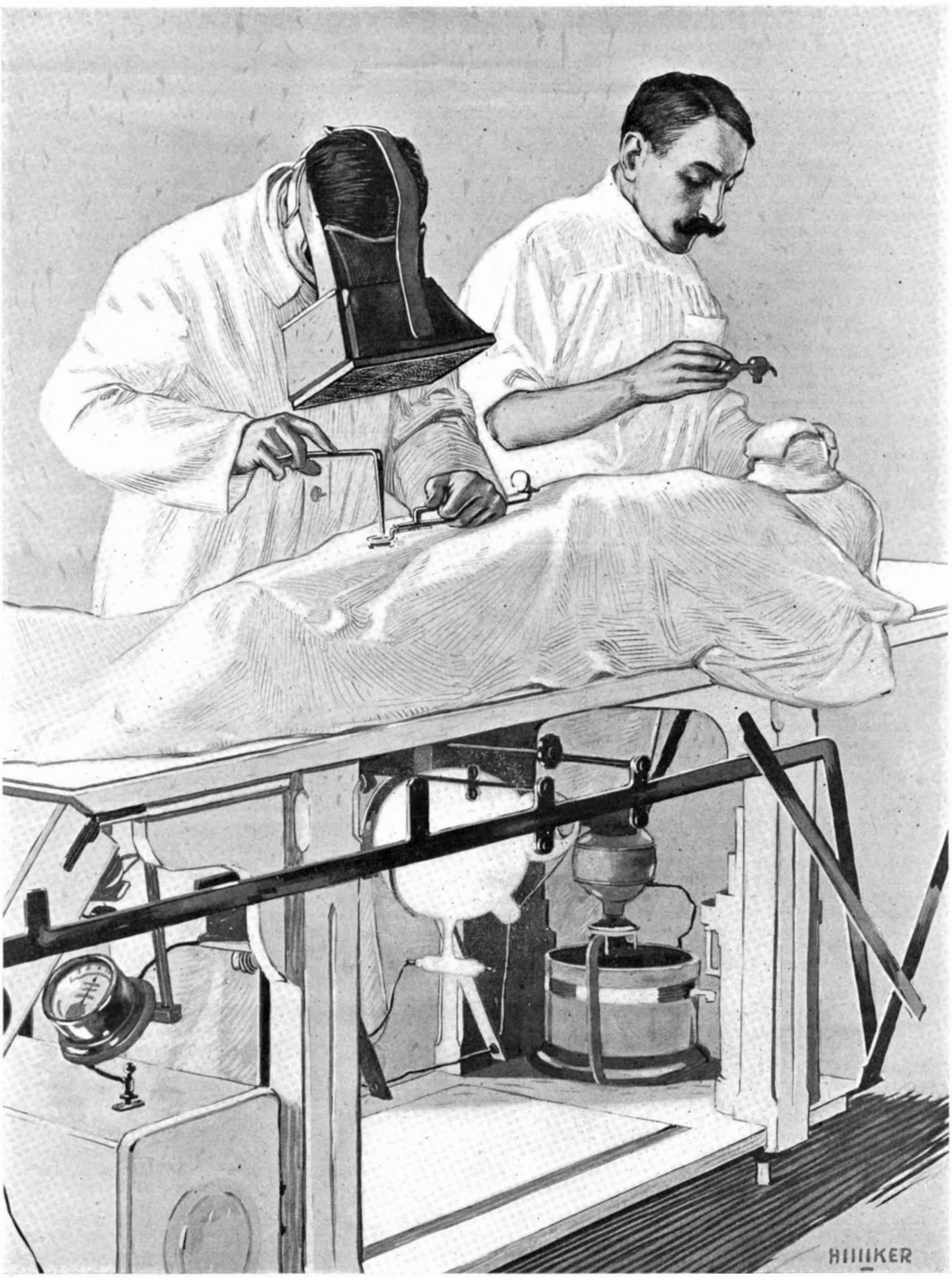

A French surgeon extracting a bullet seen by means of an x-ray.

LOCATING BULLETS IN THE HUMAN BODY BY A FLUORESCENT SCREEN.—[See page 373.]

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Radiations From Atoms and Electrons—VI*

A Study of the Character of the Mechanism Within the Atom

By Sir J. J. Thomson

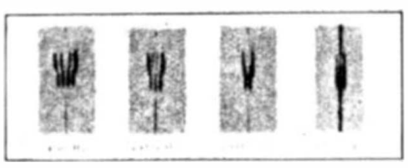
Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2109, Page 355, June 3, 1916

AT the end of his last lecture Professor Thomson said that he referred to Stark's discovery of an effect produced on the lines given out by a body when this body was exposed to a strong electric field. A number of cases were represented in Figs. 1, 2, and 3, from which it would be seen that the effect produced on the lines was by no means uniform even when these lines all belonged to the same spectral series Thus the red line of hydrogen was, it would be seen, broken up into three components, the β line into four, while the resolution of the γ and δ lines was of a still more complex character. All these lines belonged to the same Balmer series, and yet the effect of the electric field on them was, it would be seen, very different. In the case of helium, again, there were similar anomalies. The D_3 line, for example, was not affected at all, but the others were, and in increasing degrees of complexity the shorter the wave-length, the line with wave-length 3820 being, it would be seen, broken up into two sets of four components each. In the case of lithium, again, it would be seen that while one line was quite unaffected, another was broken up into two sets of three components, and still another into two sets each of four components. Thus the effect of an electric field was not only complex, but varied in the most striking way even when the lines concerned belonged to the same series. The strength of the field was 28,500 volts per centimeter.

The effect of an electric field was responsible for the great broadening of the lines observed in certain conditions. Thus when the spectrum of hydrogen was produced by the discharge through a vacuum tube, a great number of ions were liberated, and the electric field in the immediate neighborhood of one of these ions was very large. Hence a luminous atom, if close to one of these ions, would be emitting its light in a strong field, and its lines would therefore be split up in a manner analogous to that represented in Fig. 1. The latter, however, showed the effect of a uniform field, but the field in the discharge-tube was by no means constant. Hence the constituents sent out would be spaced at different distances from the "rest" positions of the lines, and we got accordingly not detached components, but a spreading out of the line into a kind of ribbon. We should thus expect when the lines were emitted amid charged atoms that they would broaden out and become more like bands, because the luminous centers were then exposed to strong electric fields of all kinds of intensities, giving rise accordingly to components at all distances from the normal position of the line.

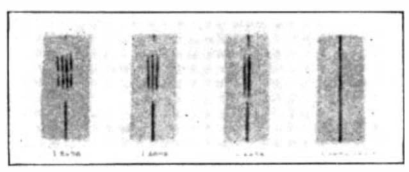
The explanation of this effect of an electric field was not yet quite clear. He might, however, call attention to a possible way of looking at the matter closely analogous to that he had adopted in describing the Zeeman effect. He had, in a previous lecture, shown that we could picture this effect if there were, in the atom, directions in which the magnetic field was very strong and if the spectral lines were due to electrons spinning round the lines of magnetic force. Anything that varied the magnetic field would alter the speed of the spin, and in consequence of this, the position of the line in the spectrum. It was natural to look to a movement of electrons as responsible for the magnetic field. In fact, if an electron described a circle it gave rise to a magnetic field very similar to that which would be produced by a current of electricity flowing round the same path. Hence a revolving electron was the equivalent of a magnet, the strength of the field produced being proportional to the moment of momentum of the electron about the center of its motion. If this moment of momentum were altered, the magnetic force would also be altered. If, therefore, we had in the atom the electrical analogue of a magnet, the position of the lines in the spectrum would be changed by the application of an external electric field. Suppose within the atom there was accordingly a negative charge lying close to a positive charge, the two forming a di-pole. Lines of force forming closed circuits would go out from this di-pole, as indicated in Fig. 4, and at a certain point the direction of this force would be at right angles to the axis of the di-pole, and an electron placed at A would be attracted in the direction of the force. If it were revolving steadily round the di-pole axis, it would produce a magnetic field having a moment proportional to $v\,a$, v being the velocity of the electron. Hence, if another electron fell into the atom and spun round the axis of the field produced in the way just explained, this incomer would have a certain definite rate of revolution. If now an external electric force were applied, the electron, the steady motion of which produced the magnetic field, would have to find a new position of equilibrium, where the external force would just balance that force of the di-pole. The orbit described by it would therefore be shifted, and the moment of the magnet equivalent to it would be changed. Hence, if an electron now fell in as before, giving rise to a spectral line, this line would be shifted from its normal position.

In another way of looking at the matter, the shift of the spectral line was attributed directly to the change in the orbit of the electron responsible for the magnetic field. It was, however, difficult to believe that the spectral lines could be due to electrons in steady motion in a circle. If such particles were emitting radiation, they must be losing energy, and their paths could not therefore be stationary. The electron would be bound to fall in, the radiation would come to an end, and there would, moreover, be no guarantee that the time of vibration of the light emitted during the process would remain the same throughout. If there were appreciable radiation from an electron traversing a steady orbit, it would accordingly be difficult to reconcile this emission of energy with the steadiness of the position of the spectral lines, which must, it would seem, be in such case drawn out into bands. If, however, there were no radiation, there would be no light. It would be seen from these considerations that there were formidable difficulties in attributing the spectrum to radiation from electrons in steady motion, and for concluding that the lines must be produced in conditions of rapid change, as when an electron entering from the exterior spun round a line of magnetic force.



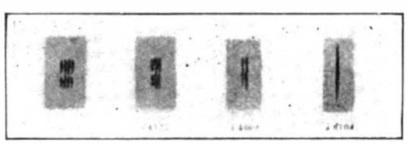
λ 4102 ($H\delta$) λ 4341 ($H\gamma$) λ 4861 ($H\beta$) λ 6363 ($H\alpha$)

Fig. 1.—Stark effect on hydrogen.



λ 3820 λ 4026 λ 4472 λ 5876 (D_3)

Fig. 2.—Stark effect on helium.



λ 3915 λ 4132 λ 4602 λ 6104

Fig. 3.—Stark effect on lithium.

One point of great importance was the constitution of the energy of light. Newton regarded light as consisting of a number of small particles moving at great speed. On his theory, therefore, light was molecular in structure, its molecules being his corpuscles, each of which represented a perfectly definite unit. On the undulatory theory, on the other hand, the energy of light (implicitly at least) was regarded as a perfectly continuous quantity. This theory had had an enormous success in explaining optical phenomena, in which connection it had long been the only one to be considered. From a historical standpoint, however, it was interesting to note that if our knowledge of the electrical effects of light had been developed in Newton's time, the case for his view would have appeared so overwhelming that the speaker did not believe that the undulatory theory would have ever got through the early stages of its development. These effects of light on electricity could be accounted for very simply on Newton's view, but were exceedingly difficult to explain on the ordinary conception of the undulatory theory. What was required was some way of combining the two so as to get the steadiness of the train needed in optical phenomena, with the individual units of energy required to account for the electrical effects. He could not, the lecturer proceeded, show at a public lecture, in quantitative fashion, the experiments which inclined physicists to believe that light had some kind of molecular structure. Evidence of the most straightforward kind was, however, afforded by the action of light on a plate of metal. If, for example, ultra-violet light were allowed to fall on such a plate, it made the metal shoot out negatively-charged particles, and with some considerable velocity. This velocity could be measured by finding to what positive potential the plate must be charged in order to prevent the escape of the particles. Investigations thus made showed that the velocity with which the particles shot out, did not depend in the least on the intensity of the light, but only on its quality. On the undulatory theory, it would be natural, however, to expect that the more the light energy falling on the plate, the greater should be the speed of the particles shot out. Actual experiment, on the other hand, showed that this speed was the same whether the source of light were close up to the plate or the length of the room away. So long as there was no change in the quality of the light used, the energy in each little particle shot out was simply proportional to the number of vibrations made per second by the exciting light. This energy (E) was, in fact, given by Planck's relation, viz.:

$$E = h\,n,$$

where h was an absolute constant and n the number of vibrations made per second by the light. This was a very remarkable result. The energy of the particles did not depend upon the amount of light energy falling on each unit surface of the plate, but only on the frequency of this light, and with this frequency it was connected in the above very simple way.

The kind of effect discussed above was shown by the lecturer by an experiment in which a metal plate was connected up to a gold-leaf electrometer, and exposed to the action of ultra-violet light. With the plate negatively charged the electroscope was rapidly discharged, while when the plate was positively electrified there was no loss of charge; the negative particles which would otherwise have been liberated by the action of the light being retained by the attraction of the positive charge. By measuring accurately what positive charge just sufficed to stop the emission the velocity natural to the particles could be determined. The results showed that this velocity depended solely on the wave-length of the light, being, when due corrections were made, independent even of the nature of the substance acted on. This result could be easily explained on Newton's view, according to which, if more light corpuscles struck the plate, more particles would be liberated; but the speed with which they came out would be unaffected. On the undulatory theory, however, this was the reverse of what would be anticipated.

Experiments of the kind illustrated afforded one piece of evidence in favor of a corpuscular constitution of light; another was derived from the effects produced when light of less than a certain wave-length was passed through vapors. The effect was to make these vapors conductors of electricity. This the speaker showed by passing the light of an arc through quartz windows and into a quartz vessel filled with vapor of mercury. A plate placed in this vessel was connected up to a charged electroscope, and it was shown that the action of the light was to cause a rapid loss of charge. When, however, a thin piece of glass was interposed in the path of the beam of light, the discharge ceased, since it was only ultra-violet light which had the property of making the vapor a conductor, and this light was stopped by the glass. Accurate measurements, the lecturer proceeded, showed that the effect on the vapor appeared quite suddenly with a certain definite wave-length in the light. It could not be produced by ordinary visible light, however intense, and the action of the most powerful arc had no effect if its light passed through glass on its way to the vapor. To be effective the wave-length of the light must be less than a certain definite value. With light of the proper wave-length, however, the conductivity produced was proportional to the intensity of the light.

This again could be explained on Newton's view. To make the gas a conductor a certain energy was required to knock out negative particles from its atoms. An "ultra-blue" corpuscle had sufficient energy to do this, but a "red" corpuscle had not. The fact that there was no effect whatever the intensity of the light, if of wrong wave-length, was, on the other hand, very difficult to explain on the undulatory theory.

*From the *Engineer*.

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Further evidence in favor of Newton's view was provided by a study of the ionization of gases by Rontgen rays. These rays were a variety of light, but owing to their very short wave-length their effect in rendering gases conductive was very pronounced. Experiment showed that the phenomena followed a very simple law. The earlier experiments indicated that if the whole of the Röntgen rays were absorbed in a gas, the number of charged particles produced was independent of the nature of the gas. In short, so long as the rays were completely absorbed, the number of negative particles produced was the same, whatever the absorbent used. Guided by these observations, the speaker had put forward an explanation of the phenomena. Subsequent experiments had, however, shown that the law was not accurately fulfilled in the case of certain gases, but still more recently Barkla had proved that if expressed in one way the law was perfectly true. Under the action of Röntgen rays the molecules of the gas acted on emitted negatively-charged particles, which had a very high velocity, and these negative particles were the primary cause of the conductivity found. This conductivity was not due to the direct effect of the Röntgen rays, which merely caused a small number of molecules to expel these high-speed electrons, and these then ionized the gas and made it a conductor. Barkla had proved that the number of these primary high-speed particles produced by a given beam of Röntgen rays was the same whatever the gas acted on, provided that in each case the rays were completely absorbed.

With this proviso, whether the gas acted on were hydrogen or the heaviest known, a primary electron appeared in the gas for every "unit" comprised in the bundle of Röntgen rays. This was exactly the kind of evidence which was thought convincing in proving the existence of "atoms of electricity" in electrolysis, and it was equally forcible in proving the molecular constitution of the Röntgen rays. Each high-speed electron produced by the latter was thus, in short, accompanied by the disappearance of some unit in the Röntgen rays.

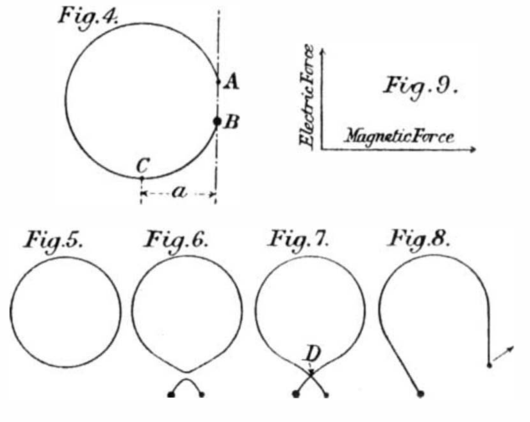
In considering such matters a mechanical model was often of assistance, and the Röntgen-ray unit might perhaps be looked upon as a line of electric force in the shape of a complete circle which moved through space with the velocity of light. The direction of the force being tangential to the line, the component in the direction of the motion would have a periodic character varying according to a sine law from plus in front to negative behind. If this unit approached a neutral atom, which was a doublet consisting of a positive lying adajcent to an equal negative charge of electricity, the interaction of the two would be somewhat as represented in Figs. 5 to 8. The moving circular line of force would bulge out as indicated in Fig. 6, while the line of force between the two charges would bulge upward as indicated. At a later stage the two would meet as in Fig. 7.

There would thus be a tendency for the ring to break at the point *D*, and this break would take place if the electric force in the ring were stronger than the electric force between the positive and negative charges in the atom. We would thus get the condition represented in Fig. 8, the negative particle being torn out and shot off at great velocity. In this process the Röntgen-ray unit would evidently be broken up and disappear, its energy being transferred to the electron which it had caused to shoot away. On the other hand, if the force in the ring were less than that uniting the di-pole, the ring would wriggle free and go on unchanged. The process above described could be reversed, and a Röntgen-ray unit produced from a cathode particle.

Similar ideas would apply to ordinary light, of which a Röntgen ray was only one form. Such units as described would take the place of Newton's corpuscles, and all would proceed swimmingly so long as we had only to deal with electrical phenomena. The trouble came in when we had to explain other properties of light. Thus optical phenomena required the existence of a regular sequence of such units extending over, say, 100,000 periods. On the other hand, the natural view was that all such units would be independent of each other, and in that case it was difficult to see how the necessary regularity of phase was to be provided if light were due to the ejection of units of this kind.

The speaker's view was that the necessary regularity of phase was imposed on the units by the medium through which they traveled. Only those particles which showed the necessary regularity would get through, the others being sent back till they had learned to arrive in the right phase. In this connection a remark made by Stokes had been far too frequently ignored. Stokes observed that, to get refraction, the vibrations must continue for a considerable time. The first few vibrations received should go straight through the medium without being refracted, and refraction would only arise after something had been set swinging in the atoms of the refracting body. This idea was applicable to light units of the nature sketched above. Suppose that something in the volume of the body was set in vibration by some light unit which had just fallen into it, disturbing the electric field of force in the atom. If another light unit came up with its field of force parallel to the then instantaneous direction of the electric force in the atom, it would get through without difficulty. If, however, the two fields were in opposite directions, and that of the atom were the stronger, the light unit would be repelled.

For example, on the electro-magnetic theory of light, if the vertical (Fig. 9) denoted the direction of the electric force in light, and the horizontal that of the magnetic force, the direction in which the energy was propagated was at right angles to both forces, and in the case indicated would be out from the paper. If the electric force were reversed, the direction of the flow of energy would also be reversed. Hence when a unit of light came up to an atom disturbed by the passage of a predecessor, it might find the electric field inside the atom opposed to its own field, and would consequently fail to get through. Any violent difference in phase would thus give rise to a sorting out of the particles. If exactly in phase they would get through without difficulty, but otherwise be repelled, to come back again as the opposing force fell off. They would, so to speak, keep knocking and knocking at the atoms of the medium until the conditions were such as to permit of their passage. In this way the medium would impose on the light units a regular sequence of phase. The particles could not, in short, get through as a dis-



organized crowd, but must keep in step, the resultant uniformity being therefore imposed by the medium, and not impressed on them by their source. On this view the latter kept on erupting units irregularly, which were afterward drilled into step by the medium.

Along these lines he thought it would be possible to obtain the uniformity required in optics, and to still retain the units, the existence of which seemed necessary to account for the electrical effects.

In this connection he would observe that, in order to explain certain optical phenomena, Newton had been led to endow his corpuscles with "fits of easy transmission" and "fits of easy reflection." If the corpuscle met the surface of a medium during a fit of easy transmission, it passed through, and in the contrary case was reflected. On the rise of the undulatory theory a good deal of satire had been heaped on the arbitrary and artificial character of this conception, but on the electro-magnetic theory of light Newton's "fits" formed a just corollary to our conception of the way in which the energy was transmitted through an electro-magnetic medium. If light came up to an atom and found the intrinsic electric field of the latter in the same direction as its own, the light would proceed in the same direction as before, and, in Newton's language, would be in a "fit of easy transmission." If, on the other hand, the two fields were oppositely directed, and the atomic field were the stronger, the light would be pushed back. Hence, taking the most modern views as to the transmission of energy in an electro-magnetic field, Newton's method was one way—and by no means a bad way—of describing the process.

In some such way as the foregoing, it would, Professor Thomson concluded, be possible to retain the essentials necessary to explain optical effects with the atomic constitution needed to account for electrical phenomena.

The Visibility of Distant Objects in Warfare

The long range of weapons employed in modern warfare has given importance to the study of the appearance of distant objects. A constant contest is taking place between the observer trying to locate the position and numbers of the enemy and the observer who endeavors by all possible means to conceal these factors.

Generally speaking, an object becomes indistinguishable when its brightness and color are identical with its surroundings. For this reason such colors as gray and khaki, which blend well with the surroundings, are preferred for modern uniforms. Yet their effectiveness in this respect depends on the nature of the ground over which troops are moving. Khaki is doubtless difficult to distinguish amid sandy wastes; gray or green might be better against grass or foliage. Of all colors, red is the most conspicuous at a distance. Not only is it the color which presents the most vivid contrast with the ordinary background, but there appear to be certain physiological factors which accentuate this impression. For example, it is well known that the central region of the eye (which is mainly used for the observation of distant objects) is highly sensitive to the red end of the spectrum and correspondingly insensitive to blue and green. It has also been alleged that, owing to the eye lens not being achromatic, most people find it difficult to focus distant blue and violet light; and that such objects readily merge in the landscape because their outlines are hazy and blurred. Skillful gardeners in designing a flower-bed arrange the blue and lilac flowers in the foreground when possible, and rely on vivid red and orange blooms for a distant effect.

It is known, however, that in a dim light the conditions obtaining in full daylight do not apply. In a feeble illumination the eye becomes more or less color-blind and is highly insensitive to red, which appears dead black, whereas green and blue objects appear an uncanny gray. A party of men in gray-green uniforms, advancing across a grass field in twilight, would therefore be extremely difficult to detect.

All this suggests that the problem of selecting an inconspicuous uniform is a complicated one, especially when it is borne in mind that it is also important that bodies of men, besides being inconspicuous to the enemy, should be clearly visible to their own side. It has been suggested that this condition might be secured by differentiation in the coloring of the front and back of the uniform.

It is interesting to observe that on several occasions during the present war scouts have taken special steps to accommodate the color of their clothing to the surroundings. For example, it is stated that the Germans provided some of their men with white uniforms in order to match the snow in the Polish campaign, and that the Turkish snipers in Gallipoli painted their hands and faces green so as to be indistinguishable amid foliage.

It is clearly more difficult to secure resemblance to surfaces which are constantly changing, such as the sky and the sea. But there is a second principle which can also be used to secure inconspicuousness in these circumstances, namely, what may be termed the "patchwork" principle. This is based on the experience that the outlines of an object may be rendered difficult to distinguish by breaking up its surface with stripes and patches. This method has been applied to aircraft and hydroplanes and to forts and temporary defenses of various kinds. Besides painting the hulls and funnels of warships a slaty-blue or "battle-gray," experiments have been made with mottled patches of black and irregular serpentine black lines painted on a gray background. Some experiments in this direction recently carried out in the United States Navy are said to have been very successful, and it may be only a question of time before dreadnoughts are rendered practically invisible at the long range of modern sea-battles.

A combination of patchwork and imitation of surroundings may also be applied with good results in order to conceal aerodromes and similar objects. For example, if the adjacent ground is cleared and the grass is scraped away at intervals, leaving bare patches, and if the aerodrome itself is painted a patchwork of brown and green, identification from above becomes very difficult. Yet another instance is furnished by the recent correspondence in the *Times* regarding the color of sandbags. It is stated that the Germans insert black sandbags at intervals among those of lighter tint. An officer at the front wrote: ". . . It was the first thing I noticed about the German trenches. Their patchwork device made it impossible to spy their loopholes, whereas ours take a long time to build and then are easily seen."

A device such as this, which would apparently save a considerable number of lives in a long campaign, is well worth attention.

There remains one other possible device for concealing objects which, although difficult to apply, is probably the most perfect of all when realizable. This is to make use of mirror or semi-mirror surfaces which reflect their surroundings and thus automatically imitate them. Such a device would be applicable in any surroundings.

The chief instance known to the author of the use of this method is afforded by the latest Zeppelins, which are reported to have a coating of bright aluminium powder, which reflects the sky and makes the vessel very difficult to detect at any considerable height. For aircraft flying at a height the problem of concealment is a particularly difficult one, as whatever pigment is adopted, the framework is seen silhouetted against the bright sky. It is possible that by making use of reflecting surfaces, in addition to the other devices mentioned, this contrast could be considerably lessened. If to a noiseless engine could be added the quality of practical invisibility, aircraft would become very much more dangerous offensive machines than at present.—*Nature.*

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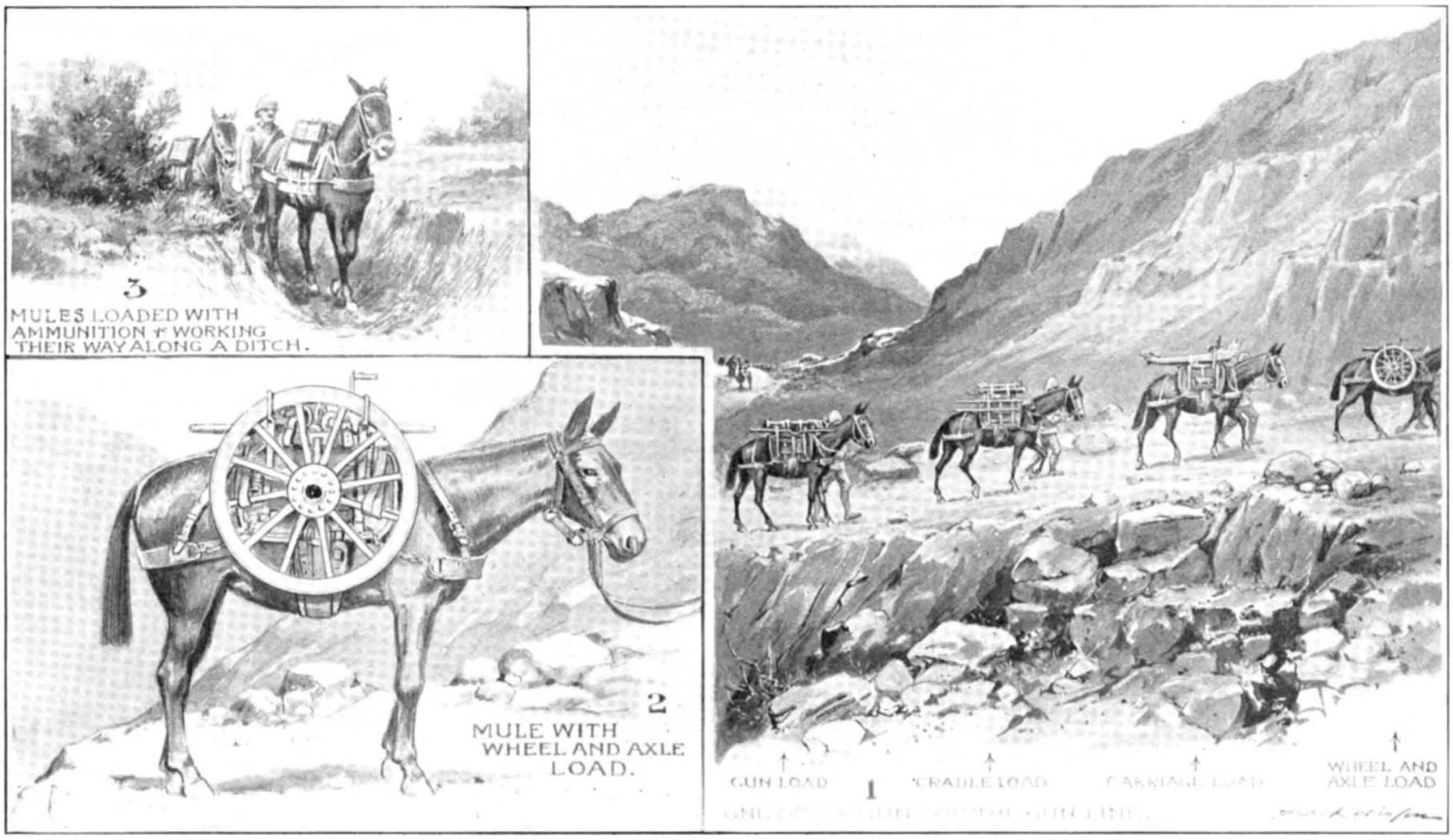

Courtesy of The Illustrated War News.

"Pack Artillery" is another name for Mountain Artillery, the meaning of which is explained by the illustration above. A mountain battery is divided into a "Gun Line" and an "Ammunition Line." Six guns and twelve ammunition-mules form the "Gun Line." The "Ammunition Line" establishment consists of thirty-six mules which bear the ammunition. There are about the same number of relief mules and mules carrying stores, etc. Fig. 1 shows the order of a sub-section of a "Gun Line" when on the march in "Column of Sub-sections." Four miles an hour is the normal rate of marching, with intermittent trotting for short distances. Where road space permits of two sub-sections marching abreast, "Column of Sections" is usual; and in open ground, "Battery Column."

The Mountain Gun and Mule Team*

How Light Guns of Special Construction Are Transported Over Rough Ground

In mountainous districts where no roads exist it is impossible to use ordinary field artillery, simply because transport on wheels is out of the question. To meet this difficulty a light mountain-gun is used, this weapon being so designed that it can be rapidly taken to pieces and the individual parts loaded on the backs of a number of mules, varying from three, in the case of the smallest gun, to five in the larger types. The 2.95-inch quick fire mountain-gun may be taken as a good example (Figs. 1 and 4). In its case, one animal, known as the "gun-mule," carries the gun-barrel, or "chase," with its details; another, the "cradle-mule," carries the cradle, or frame, in which the gun rests when put together for action; a third animal, called the "carriage-mule," transports the gun-carriage, or trail; and the "wheel-and-axle-mule" completes the team, carrying those parts on its back (Figs. 1 and 2). A gun carried in this manner can be rapidly conveyed over rough ground to otherwise inaccessible positions, and, if advantage be taken of available cover, it generally happens that the transport of the gun can be carried out with the minimum risk of discovery by the enemy. The gun and its parts and gear can be removed from the pack-saddles, put together, and made ready for action within the space of a minute.

A gun-mule, it is a curious fact, instinctively acquires special experience during his spell in the service of the battery, which extends in some cases over a period of twenty years, and that experience on the part of the animal adds considerably to the efficiency of the battery. A well-trained mule, for example, will always select the easiest path, and in climbing a stiff gradient will sometimes, if he can get hold of a convenient scrub bush or branch for the purpose, help to pull himself up by his teeth. Again, trusting to the gunners holding on to his tail as a brake, a trained mule will, without hesitation, slide down an incline of 45 degrees. When with the 2.95-inch quick fire mountain battery, the gun-mule carries a weight of 330 pounds; the cradle-mule, 300 pounds; the wheel-and-axle mule, 302 pounds; and the carriage-mule, 343 pounds. These weights can be carried by the same animals all day if necessary, but it is usual to provide relief-mules, to which the loads can be transferred in half a minute as they trot up alongside for the purpose. A mule battery can often be very useful even in a level country, as it can be rapidly and secretly brought into action along a ditch (Fig. 3) or a foot-path through a plantation where such a course would be impracticable with a battery on wheels. In exceptional cases, when the mules cannot safely get up to a difficult position, the gunners themselves can turn to in their places and carry the various parts of each gun in a battery to the desired point, so as to come into action without delay.

When a battery is traveling by road, the guns are put together and their carriages fitted with a pair of shafts each, so that they can be drawn in the usual manner instead of being carried on the backs of the mules.

The 2.95 quick fire mountain-gun (Fig. 4) consists

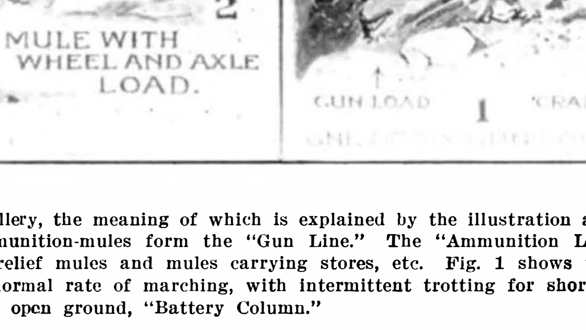

Fig. 4.—Details of a 2.95 mountain gun as put together for action.

For convenience in making the diagram clear, the near wheel of the gun-carriage does not appear. The second recoil-cylinder is on the farther side of the gun-barrel, and is consequently not visible in the diagram.

of a trail and carriage *A* supported on its road wheels *B*. Resting on the carriage is a cradle *C* in the form of a cylinder which incloses the gun-barrel, or "chase" *D*. To the cradle *C* are attached a pair of piston-rods *E* which carry recoil-controlling pistons within the recoil cylinders *F*, the latter cylinders being rigidly fixed to the carriage *A*. A column *G* is attached to the cradle *C* to carry the "sight" of the gun. Eye-bolts *H H* are provided by means of which the "cradle" and the "chase" are secured to the pack-saddles for transport. In the Vickers-Maxim mountain-gun the trail is divided into three pieces, so that one or both of the after-parts can be removed when it is desired to use the gun in a cramped position.

The shell fired by the British 2,95 quick fire gun weighs about 13 pounds; that of the Krupp gun of the same caliber, 14.3 pounds. There is, in addition, a Krupp mountain-howitzer carried by twelve mules which weighs just over a ton and fires a 27-pound shell.

*The Illustrated War News.

Vertical Gas Retorts

In a paper read before the Edinburgh and East Scotland Section of the Society of Chemical Industry Mr. J. W. Napier told of his experience with vertical retorts for making coal gas at the Alloa works, of which he is the engineer and manager. Vertical retorts had been in use for the past two years. Compared with the old system of horizontal retorts, the new system required about one fourth only of the number of men, the saving in labor charges being about 1s. 2d. per ton. Two thousand cubic feet more gas was got per ton of coal, the yield of tar increased from 9 to 15 gallons, and sulphate of ammonia increased by 20 per cent. The total increased value obtained was found to be 3s. 8d. per ton of coal used. The vertical retort had solved the labor problem at gasworks, giving conditions of working that satisfied the workmen. Much investigation still remained to be done in increasing the amount and value of residuals, and economics in this direction lay principally with the chemist.

Drift Problems in Optics

When light passes through a substance, such as glass or water, the velocity of propagation is less than that in a vacuous space, the ratio of the velocity in a medium to that in free space being the reciprocal of the refractive index. This is in accordance with the wave-theory of light, and has been verified by the experiments of Foucault and Michelson. If now the transparent medium is in a state of steady motion along the direction in which the light is traveling, we should expect that the velocity of the light as measured by apparatus not partaking of this motion would be increased or decreased according as the matter moved with or against the direction in which the light traveled. Experiments by Fizeau showed that this is indeed the case: the light drifts with the moving matter. The effect is to add a velocity to that of light in the stationary medium.—*Knowledge.*

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Locating Bullets in Human Bodies

Operations Made Accurate by the Roentgen Ray

In order to extract a bullet from the human body, it is necessary to know the location of the bullet very exactly. This is especially important when the bullet is lodged in the thigh, head, chest, or abdomen. There are several known radiographic and radioscopic methods of determining the depth of a bullet in the body, but all of these methods involve delicate measurements with a scale of centimeters and more or less complicated calculations.

Dr. Wullyamoz, of Lausanne, has devised a method of reading this depth directly on the fluorescent screen, as distances are read in a telemeter. This method is based on the following facts:

1. A Roentgen ray tube in the position P (Fig. 1) projects the shadow of a bullet at A upon the point B of the screen. If the tube is moved from P to P^1 the shadow of the bullet moves from B to B^1. This displacement of the shadow, BB^1, is directly proportional to the bullet's distance from the screen and inversely proportional to its distance from the Roentgen ray tube.

2. If a strip of black paper in which notches and figures have been cut is illuminated from the back the notches and figures will appear white on a dark background. The illumination may be produced by a fluorescent screen behind the paper.

If the displacement of the Roentgen ray tube (say 10 centimeters or 4 inches), the distance of the anticathode below the operating table (25 centimeters or 10 inches) and the height of the fluorescent screen above the table (25 centimeters or 10 inches) remain unchanged, a given displacement of the bullet's shadow always corresponds to the same depth of the bullet in the body.

The apparatus required in addition to the Roentgen ray tube and the fluorescent screen is easily constructed. It comprises a slide, with stops, for limiting the displacement of the tube, the notched scale of black paper, and a support for the fluorescent screen. This support is made of three boards, 15 centimeters (6 inches) wide, put together so that they form a bridge 25 centimeters (10 inches) high and at least 55 centimeters (22 inches) long, over the patient (Fig. 1).

The scale shown in the illustration is graduated by the graphical method indicated by the dotted lines of Fig. 1. The vertical line $A\,B^1$ is divided into centimeters, and through the division marks lines are drawn from the limiting position of the tube S to the scale, where they determine the positions of the notches. The fifth, tenth, and twentieth notches are made deeper than the others, and are also indicated by cut-out figures.

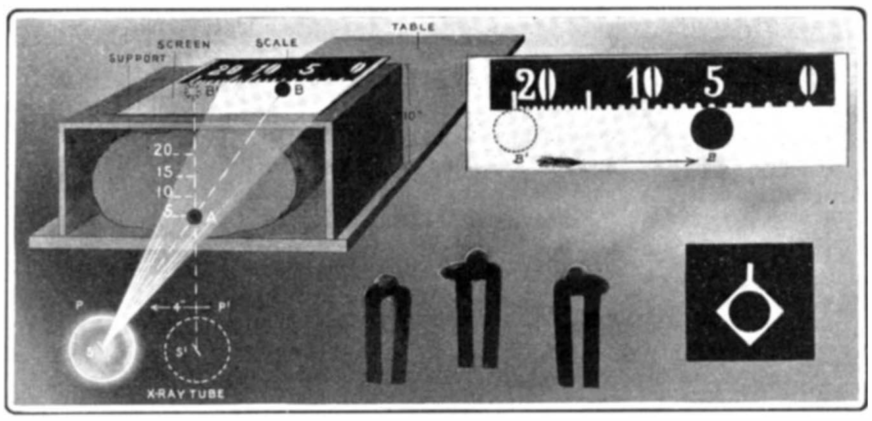

Fig. 1.—Sketch showing operation of the apparatus, locating scale and diaphragm.

This scale being pasted on the glass of the fluorescent screen, the notches and figures appear luminous when the screen is exposed to the Roentgen rays.

In measuring the depth of a bullet, which can be done in a few seconds, the following procedure is adopted:

1. The patient is placed on the radioscopic table and the bridge carrying the fluorescent screen is placed over him. The Roentgen ray apparatus is set into action and the position of the bullet in the horizontal plane is very accurately determined by means of the screen.

2. The diaphragm which limits the beam of Roentgen rays is contracted until it closely frames the bullet or other projectile in such a manner that the point of a rifle bullet or shell splinter, or the center of a shrapnel ball, occupies the center of the aperture of the diaphragm.

3. The screen is so adjusted that the last, or twentieth, notch of the scale coincides with the middle of the upper edge of the diaphragm aperture, the Roentgen ray tube being directly beneath the bullet and in contact with one of the stops that limit its motion.

4. The diaphragm is opened wide and the tube is moved to the other stop. The number of the luminous notch that appears directly over the image of the bullet indicates, in centimeters, the depth of the bullet, i. e., its vertical distance from the part of the skin in contact with the table.

The surgeon then proceeds to extract the bullet in the manner shown by the cover illustration.

The Roentgen ray tube, coil and accessories are mounted on a shelf attached beneath the operating table, and the surgeon keeps the bullet and the anatomical details continuously in view by means of a fluoroscope attached to his head. In some cases the ordinary instruments cannot be used because they would hide the bullet. For such cases Dr. Wullyamoz has devised pincers with their tips bent at right angles, as seen in the large illustration. The point of the scalpel is made to coincide with the radiographic shadow of the bullet and the skin is incised at that point. The pincers are inserted, with their tips coinciding with the bullet's shadow. The pincers are then thrust in until they reach the bullet, when they are opened to seize it. In this way a small projectile of any shape can be extracted in less than one minute without producing any unnecessary laceration.

Correspondence

[The editors are not responsible for statements made in the correspondence column. Anonymous communications cannot be considered, but the names of correspondents will be withheld when so desired.]

Leaf Photography

To the Editor of the Scientific American Supplement:

Referring to the article on "Leaf Photography" in the Supplement, No. 2104, page 277: I beg to call your attention to the fact that the same result may be produced on the human skin by prolonged exposure. My attention was called to this at Newport many years ago by sitting, at a dinner-party, opposite a young lady who had spent the day on a yacht, and had on her neck and shoulders a reproduction in sun-burn of the pattern of the lace in the shirt-waist she had worn.

I was led to experiment at the beginning of the next summer, before my own arms had become sun-burned, with various protecting media. Common rubber adhesive plaster gives perfect protection, and stays on until it is intentionally pulled off. Any design which can be cut in plaster, such as a monogram or a profile head, is left white as the surrounding skin darkens by sun-burn. More than this, a head from a strong negative, such as is shown in your article, can be printed by attaching the negative, which must be, of course, of flexible film, to the skin with collodion. The longer it is left on, the better the print. A week or two gives a good result. M. D.

April 28, 1916.

Burning Kerosene Successfully

There is probably none, be he manufacturer or engine operator, who has not, at one time or another, attempted to use kerosene in the ordinary gasoline engine. In so doing, they have learned, usually by hard knocks, that it is not so easy as it may have seemed. We use the term "hard knocks" advisedly and in a literal sense, because one of the first effects noticeable in the use of kerosene in the average engine is a sharp knock caused by permature ignition or release of explosive gases. It is because of this knock that the majority of kerosene engines are supplied with some system of water injection.

In order to understand why water injection overcomes this knock, we must first know the cause of the knock. Kerosene, distillate, and other of the low gravity fuels, have a somewhat contradictory feature, in that, while the temperature of evaporation is high, as compared with gasoline, the ignition temperature, of a mixture of their vapor with air, is lower than that of a mixture of gasoline vapor and air.

We can, usually, carry the compression of a gasoline engine to 85 pounds per square inch, or higher, without getting premature ignition. But let the compression of a kerosene engine, without water injection, exceed 70 pounds prematures are quite sure to occur. However, by injecting into the cylinder an amount of water equal to the amount of fuel used, we may use kerosene at the same compression as gasoline.

The reason why water in the mixture overcomes the knock has long been a puzzle to gas enginemen. Many theories have been advanced to explain just what function is performed by the water in the mixture. For example, some claim that the dissociation of the water into its constituent gases delays combustion. Others give it as their opinion that the steam formed delays the combustion, etc. As a matter of fact, the real function of the water lies in keeping down the temperature of the mixture, so that the ignition temperature is not reached at the compressions used for gasoline.

This is easily proven by the fact that more thorough cooling of the walls of the compression space, without water injection, will accomplish the same purpose. Manufacturers of large engines, using water-cooled pistons and water-cooled exhaust valves, have run the compression of their gasoline engines up to as high as 110 pounds per square inch. There is a well-known distillate engine that uses regularly, with water injection, a compression of 100 pounds. Considering the other extreme, it is well known that the compression of an air-cooled engine must be kept down to about 45 pounds per square inch. The fact that an engine has been built and operated with water injection as the only means of cooling, shows conclusively that this cooling is the function performed thereby.

Holding down the compression temperature does not, alone, solve the problems involved in operating on kerosene. Even with efficient cooling, complete combustion is not necessarily assured. This is easily shown by the nauseating character of the exhaust of the average kerosene engine. Compensation for change of speed and load is a problem much more difficult of solution in the kerosene engine than in the gasoline engine. Many a kerosene engine will operate very well on full load and either run lamely or stop altogether on light loads. While the gasoline engine will stand fifty per cent excess of fuel in the mixture, a very slight change in the proportions will cause the kerosene engine to become erratic in its performance.

Whatever may be said of the value of water injection, it is undeniable that it adds complications. The simpler we can make an engine, especially one intended for the average operator, the less trouble it will give. Therefore, if the engine can be made to operate just as well without water injection and accomplish this without complication, the nearer fool proof it is.

In some of the most recent designs of hot-bulb oil engines water injection is not used, although the engines are designed expressly to operate on the heavier fuels. If a device can be applied to the standard type of gasoline engine, which will permit the use of kerosene, and even heavier oils, not only without water injection, but with a clear and odorless exhaust as well, we may consider that it will fill a long felt want. There are several makes of carburetor, for which it is claimed that these results have been brought about.—*From an article by E. W. Roberts in The Gas Engine.*

Direct and High-Angle Fire

At 45 degrees, and a few degrees above and below this elevation, the shooting of a howitzer is wild, and therefore shooting at the highest angles should be undertaken from 50 degrees upward. At 65 degrees some of the shell fall base first, while at 75 degrees they all fall base first, giving very irregular shooting. Therefore the practical limits for high-angle fire are between 50 and 65 degrees of elevation. Gen. Rohne reckons that the lateral dispersion is in direct proportion to the time of flight, that is, about double the dispersion with direct fire; the dispersion in depth is, however, not much greater. The striking velocity is much the same as with direct fire, but the penetration against a horizontal target is from 2 to 5 times as much as with direct fire. Therefore for penetration it pays to use high-angle fire at over 50 degrees elevation, while for accuracy it pays to use the lowest elevation that will reach the target.—Extracts from *Précis of Artilleristische Monatshefte.*

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Economy in Study—IV

Is Your Thinker in Order?

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

THE ordinary supposition among the educators of the world is that the thinker of the average student is *not* in order. This, I take it, is one of the deeper of the objections to the present educational system, that it does not teach students to think for themselves. A truly educated man knows how to think, and moreover he has the process habituated and in easy action. It is said with truth that the present school system does not educate, in this sense, at all. As a school-boy said to Sir Gilbert Parker, "I am sick of information; I'd like to think a bit, but I haven't time. It's stuff me with things I learn to-day and forget to-morrow." This expresses the opinion of all "thoughtful" students, and this condition is the same in the school systems of the whole world. A dictionary has facts but only man has thoughtful reason.

Read Emerson on "Self Reliance": "To believe your own thought, to believe that what is true for you in your private heart is true for all men—that is genius. Speak your latent conviction, and it shall be the universal sense; for the inmost in due time becomes the outmost, and our first thought is rendered back to us by the trumpets of the Last Judgment. Familiar as the voice of the mind is to each, the highest merit we ascribe to Moses, Plato, and Milton is that they set at naught books and traditions, and spoke not what men but what *they thought*. A man should learn to detect and watch that gleam of light which flashes across his mind from within more than the luster of the firmament of bards and sages. Yet he dismisses without notice his thought, because it is his. In every work of genius we recognize our own rejected thoughts; they come back to us with a certain alienated majesty. Great works of art have no more affecting lesson for us than this. They teach us to abide by our spontaneous impression with good-humored inflexibility then most when the whole cry of voices is on the other side. Else to-morrow a stranger will say with masterly good sense precisely what we have thought and felt all the time, and we shall be forced to take with shame our own opinion from another."

The reform of the school-system in this respect, that annually $800,000,000 system, is a matter of many, but an individual may reform himself in this regard in as many weeks. He may learn to think, and "learn himself"—more or less in this manner, indeed, you may keep your thinker in order.

Every one of you has some kind of a thinker, for, probably, no really feeble-minded person is reading this advice, and certainly no idiot: these have them not. In some cases your thinkers are atonic and small, and not now of much use. But they may be developed if you *will* to develop them. These are the thinkers of the relatively stupid people. In some cases your thinkers are well developed, but rusty and dried out; these need a thorough cleaning and oiling and *use*. These are the lazy students. In some cases the thinkers have parts which are likely to break down at any moment. These are the illogical minds and the guessers. In some cases your thinkers are normal, but have the uncertain and difficult action of *newness;* they are not used nearly enough to make them run smoothly; they should be oiled with intelligence and energy. These are the average minds. To adopt a more biological metaphor, unused thinkers, like all the other organs, tend to atrophy, and fibrosis or sclerosis is the neglectful result of inadequate action. On the other hand it is as delightful, as it is useful, to take systematic exercise, and so to become an intellectual athlete. But how *few* can be made to realize this! The process, as well as the product, is a continual delight, and it is the most essential process in the mind's action.

The factors of education are more numerous than many suppose, and each one requires thought and teaches thought: the home, the schools, books, one's associates, one's vocation, the stage, travel, the state, the church—learning is a process of reaction to these nine. Each of these nine factors contributes material for learning which is valuable more or less in proportion to the thoughtfulness and activity with which it is allowed to act on the learning mind. Learning is a process of *activity* of personality, and develops in quality and quantity in proportion to the individual's fitness and to the richness of his environment. In fact, thought is this reaction or part of it. This is an active receptivity; it is like the heat coming from a fire arising from oxygen and fuel—it is inevitable. Thought stands for INITIATIVE based on understanding and originality.

My girl and women readers must realize that this thinking process is less explicit in their minds in proportion as they are really feminine. The feminine mind "jumps at conclusions," has *intuitions*, that is to say, subconscious perceptions, understanding and reason fused in one and trusted in as a habit. This intuition is a fact, a valuable tertiary sexual characteristic of the feminine mind. Women and girls relatively do not reason in the bald cold method of comparison, but their intellect "gets there just the same," often better indeed than that of mere man with his technical reason. For logic is only a cold echo of the voice of the human intellect. Women have always instinctively trusted to the products of the subconscious thought in their souls. So have philosophers of the highest rank, for example Emerson. A recent example is Henri Poincaré, recently dead, a great discoverer in mathematics, an astronomer, a well known writer and thinker in philosophy. An editorial in a medical journal discusses at some length his use of thought in the subconscious mind, in part as follows:

"The question how so great a mind works is extremely interesting. Poincaré has told the story of how he reached his great discovery of the Fuchsian functions. It was not reached all at once, but by several steps. The first and most important development came to him one evening when, contrary to his custom, having taken a cup of black coffee at dinner, he could not sleep and the idea of this new mathematical mode took form little by little under these unusual circumstances. The problems which were involved came clearly before his mind and seemed too difficult for solution; so gradually he put them away and succeeded in falling asleep. The successive steps of the solution came to him subsequently, not as the result of deliberate study of the problems, but long afterward and under most diverse circumstances, at moments when he was not thinking about them. They came to him as flashes of light, almost inspirations, as it were—once when he was just about to put his foot on the step of an omnibus, again when he was crossing a boulevard, a third time in the midst of a geologic excursion with some friends when the conversation was about ordinary subjects and had no relation at all to mathematics.

"Ordinarily mathematics at least is supposed to be eminently intellectual, and its developments are connected by the most rigid logic. It might be expected, then, that it would be only in the midst of deep thinking, even absorption of mind in mathematical subjects, that great new ideas would come; but Poincaré believed that it was a subconscious mind that solved the problems. His explanation of this, which resembles that so often heard with regard to the inspiration of the poet or the musician, is that certain thoughts are passing through the unconscious mind all the time, and that, as in day-dreaming, we are never without groups of thoughts. Whenever one of these thoughts proves to be a particularly beautiful or strikingly novel conception of some kind it attracts the attention of the conscious mind and then is retained. According to Poincarés experience, then, like poetry and music, the sciences. including mathematics, owe their development not to the rational conscious mind so much as to the unconscious and involuntary faculties. There would seem to be a tireless force in man, a part of him and yet not a part of him, working, thinking, developing, which brings to the conscious entity, man, his best thoughts and discoveries."

This is an example of subconscious thought in the constructive process, which we have discussed at our second lecture as the constructive imagination. James has a somewhat similar famous passage in his text-book of psychology: *"Stop, look, and listen" to your own minds.* This is one secret of learning to think, one which women, heaven bless 'em, have known instinctively all along. Set your subconscious thinker going by deliberate, fixed, permanent intention, and then *listen!* Encourage it now and then by actively giving it full opportunity. Stop, in part, the stuffing of your mind, and thus give it every possible opportunity to work. One feeds a furnace with coal safely to get heat from it, but some schools and some individual minds are forever putting facts into the mind but never providing time to use them, in thought.

The nature of thought should receive brief attention. Thought is not reverie, musing, fancy, day-dreaming, although most so-called thought is just this, a loose associated train of ideas or notions or fancies. True thought is intimately of the nature of the human reason; is more precious, more productive, the essence of humanity, "sterner stuff" than a more or less passive reverie, for it involves the expenditure of force.

The most important element of thought is reasoning, although recall, association and other processes are of value too. In principle reasoning is extremely simple. It is a *comparison of things, and then an inference from the comparison*—what Lloyd Morgan has spoken of as "thinking the therefore." Thought then consists of two judgments; a comparison, and an inference. One might, perhaps, develop somewhat the capability of intensive thinking by actual practice in these several mental processes. Since thought as a series of efforts (we are not discussing reverie, which often masquerades under the better-sounding name of thought) consists of two deliberate (although, perhaps, subconscious) judgments, their careful discrimination, and then their comparison, with the essential, extraneous, mental process we term *inference* following, it is not unlikely that thinking of the more logical and productive kind would be furthered by *the deliberate development of these intellectual powers separately.* 1, One in practice might train and develop his power of judgment, it is possible, by making many carefully considered and delicate judgments on all kinds of propositions, thus laying a firm basis for the more productive forms of mental action. 2, One might, too, even by work as a subject of experimentation in a psychological laboratory, or by practice and effort in many other kinds of place, develop and train his sense-discrimination. Indeed this is a neglected important function of the elementary school—training of the senses, the power of delicate discrimination, the only basis of accurate judgment and comparison, which last is in turn the fundamental process of the intellect. 3, Development and training of the power of keen and novel inference is not so easily suggested as a practical procedure, for we know little about it save in the most general terms—that inference, namely, is a process of judgment based on a largely subconscious process of the association of ideas, the very essence, as it is too the very cream, of human mental activity in its ideational aspect. Obviously inference is an advanced and neutral form of association within or between the parts of the brain devoted to thought. We may at least suppose that if the preliminary processes be developed and made vigorous and habitual, the inferences would result more frequently and more usefully, leading to novel and so productive thought.

This is the essence of thought, and the most productive because it alone produces something new. Ingenuity, originality, invention and discovery in part rest often wholly on this simple (?) process of inferring something from the results obtained by comparing two things. If love "makes the world go round," thought also makes it go around its orbit, makes it revolve and advance. If love makes the days worth while, thought, as well as love, helps to make so the years.

Do not forget the matter of the *complexes* of thought and imagination and feeling already discussed a bit in our talk on the imagination. The mind works as much in thinking as in feeling or in willing on the symbolic plan. Morton Prince in his enlightening "The Unconscious," (1915) has summarized certain of the conditions of complex—or symbol—formation, memorizing, and recall, in a way well-worth quotation:

"Though the main teleological function of the unconscious, so far as it represents acquired dispositions, is to provide the material for conscious memory and *conscious* processes, in order that the organism may be consciously guided in its reactions by experience, yet under certain conditions neurographic residua [brain-"traces"] can function as a *subconscious* process which may be unconscious, i. e. without being accompanied by conscious equivalents. The latter were classed as a sub-order of subconscious processes. We saw reason for believing that any neurogram deposited by life's experience can, given certain other factors, thus function subconsciously, either autonomously or as a factor in a larger mechanism embracing both conscious and unconscious elements; and that this was peculiarly the case when the neurogram was organized with an emotional disposition or instinct. The impulsive force of the latter gives energy to the former and enables it to be an active factor in determining behavior. The organism may then be subconsciously governed in its reactions to the environment. . . .

"We found evidence showing that a conserved idea

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may undergo subconscious incubation and elaboration, and that subconscious processes may acquire a marked degree of autonomy, may determine or inhibit conscious processes of thought, solve problems, enter into conflicts, and in various modes produce all sorts of psychological phenomena (hallucinations, impulsive phenomena, aboulia, amnesia, dissociation of personality, etc.). . . .

"Evidence has been adduced to show that life's experiences, and therefore acquired dispositions, tend to become organized into groups. The latter, termed for descriptive purposes neurograms, thereby acquire a functional unity; and they may become compounded into larger functioning groups, or complexes, and still larger systems of neurograms. Whether their origin is remembered or not they become a part of the personality. Such complexes and systems play an important part by determining mental and bodily behavior. Among other things they tend to determine the points of view, the attitudes of mind, the individual and social conscience, judgments, etc., and, as large systems, may become 'sides to one's character.'"

Such, in part, is the very latest word on thoughts and ideas as they persist in the mind but for the most part just outside of the conscious process, immersed deep in that truly "Wundtian myth" the "stream" of mind. This store of ideas of thoughts, unlike most other stores, loses nothing by being drawn upon. Yet, on the other hand, it can be added to indefinitely without any crowding, the useless material being continually, as a matter of fact (see the end of the discussion of observation and note-taking) put into the scrap-pile—forgotten. Let us now, then, consider certain practical hints as to how the store of ideas or thoughts may be economically increased, on the basis of these complexes or neurograms.

Learning to think may, then, be next discussed briefly. There are here six practical points which may be noted. First. A realization of the necessity and the joy of thought to education and to success. Second. Development of interests as various as possible provided they be not too diverse and too numerous at the same time. Third. An abundance of clear concepts, or ideas, especially of relationships. Fourth. A habit of concentrated attention along more or less "rational" or logical lines. Fifth. A thought-habit developed by practice (writing), debating, reflection. Sixth. The Opportunity for thought, time and solitude.

Let us consider each of these pratical suggestions. First. *The realization of the necessity and the delight of thought.* The average boy and girl has no way of learning that what most counts is thought, initiative, active imagination. Experience alone will prove to him this. See the advertisements of the efficiency-schools. But experience shows overwhelmingly that just this chiefly makes the difference between a life of wages and a salary. Everyone has more or less information, but only a few use it in thought, and so do things that are new, or do old things in new ways, which is the next best accomplishment.

Second. *Development of interests.* Already in a previous lecture the absolute necessity of interest for learning was pointed out. The necessity is still surer for thought, true wisdom, real education. Develop interest in a subject and the subconscious will think it out by association, imagination, if given a chance, while you are *doing* something else. This involves, as we have seen repeatedly, an *effect* to furnish the motive power.

Third. *An abundance of clear ideas,* especially ideas of relationship. The relation to language is immediate here, as has been again recently pointed out by Dr. A. A. Berle in the second chapter of his interesting "Teaching in the Home," already quoted in our discussion of books and their educative use. Harvard College has recently made an extensive investigation tending to develop finally the study of English along this basal line of intimate relationship to our primal intelligence. Ideas of relationship are especially essential: by their very nature they tend to actively associate educatively, and their elaboration should be a systematic part of all school-work. The habit of the use of thesauri (dictionaries of synonyms and antonyms) is easily acquired, and there is an amazing interest in the relations of verbs, nouns, adjectives, and adverbs—things, their qualities, what they do, and how. Knowledge about these is especially essential. Especially important are books of synonyms and antonyms when the habit of using them has been acquired. Their use does much to develop thought as well as clearness of expression and literary style; they help the mind to work logically, and systematically.

Purely for emphasis it is worth repeating that words make up language and serve to connect it with the brain, and thereby the remainder of the body and the rest of the world. Words then are the quite indispensable handles of our human thinking, of our humanity itself. The closeness of this relation is worth strong emphasis, for its general educative importance is supreme.

Fourth. *The habit of concentrated attention* is necessary in thought. This concentration should be for short periods along lines not disagreeable to the human rationality. Concentration sinks ideas more deeply into the brain; how, we know not. Conscious attention, however exactly it may act, is certainly essential, but save in cases of exceptional individual interest, such as that in discoveries, inventions, etc., attention can be concentrated properly for only short periods. Professor W. H. Pyle, as a result of experiments on practice-work in using an invented set of characters instead of the ordinary letters, found that the adult's ideal period for concentrated effort of attention is thirty minutes. A second thirty-minute practice on the same day he found to be useful, but not as remunerative as the first, and after a few practices of one-half hour each, further practice on the same day he found to be useless. Thus we see that ideas stick best when they are impressed in periods of only thirty minutes, two or three times a day. We may use this as a rule for thinking; it means the importance of *keeping the brain always rested.* It is far more important than the saving of mere time. Muscles, especially in gross masses, may be fatigued without nervous harm (in fact this makes for sound sleep), but never the nerves. There are nine thousand million neurons, or nerve-units, which weigh only a few grammes together, in the human cortex: from this may be seen how minute and subtly delicate they are; so do not fail to appreciate this fear of their liability to fatigue, for it is a very real matter. At the same time the brain may be *trained,* so one need not coddle it. Most people coddle their brains!

Fifth. *Habituation to the thinking process.* Habit makes thinking much easier than at first it appears to be. Habituation makes thinking a continuous subconscious process. Just as one knows that worry is worse for the health than an occasional fright; and just as a steady drinker suffers more harm than the man who goes off on an occasional drunken spree, so, on the other hand, the continuous use of thought impresses the brain. The habit of learning-interest must be acquired, but this mental attitude soon becomes more or less permanent. Habituations of all kinds, of course, are more or less accumulative. It is "the first step that counts" we have often heard, and habit grows with what it feeds upon. Thought is a habit, subconscious like all of them. In order to acquire the thinking-habit, other habits may have to be bent or even, sometimes, broken. A. The general principle is that in proportion to the stability of the nervous system of the individual, according to age, sex, or vigor, may a habit be suddenly bent down out of existence. B. A second process of displacing a habit is busy normality. And a third, C, is replacement with some other more useful habit. In general students who are apt to read these lectures can break short off whatever habits conflict with the thinking or the study habit.

A sixth and last element in easy thinking is *Opportunity for thought in time and in solitude.* Many of use are "too busy," but with far less productive things, to really live or to really think. *One should make time, make solitude for thought.* People are often too much continuously together, especially young people. Each individual is separate, and requires individual separate thought. One in general should room by one's self, or else in some way manage to spend considerable time alone, along the seashore or brook-side or in one's room. The gentle exercise of a stroll or of a slow bicycle ride requiring little attention to itself is our ideal stimulant and occasion for thinking—unless the attention wanders too much outwardly. The time should be somehow had in which to be alone. Schools are oftentimes too crowded to allow their students to think. One can afford as a matter of dollars and cents to take an extra year in school, if one can learn to think by doing so; the time so used is a rich and certain investment. In default of better time, a half-hour after waking and before rising is a good time to think, and many people have their most productive and original thoughts occur to them thus in the morning early after a good night's rest. The night's subconscious grist then tends to become conscious. The nervous system will be found thoughtful if an opportunity be given it.

This advice to *make thought-time at any cost* is well-considered advice, not an idle notion. It is wholly practical and expedient. It is, in fact, very often a matter of dollars and cents, and of advancement, not one only of developing one's soul and personality, which much of the world has not yet learned to value.

Rules for thinking are wholly unnecessary even to a young student. The normal human mind always knows how, as part of it is normality. Possibly no other animal knows how, but man knows how, and so do all normal boys and girls. The only explicit rule for thinking is, *Acquire the habit.* It is laziness, of course, in plain language, that more than anything else prevents this habit of thought, for with all this interest and delight, to learn to think, to become a thinker, it is not always easy in this unresting world which never stops its hurry. Some really do not know how, but only because they have never tried to learn. The vast majority are just simply too lazy to put their thinkers in order and to use them. And this is so, notwithstanding that constructive mental action is a great delight as well as by far the most practically productive process of the mind. A few of my readers may here be "thinking," or even saying in annoyance, "I did not buy this book to be accused of laziness." No, indeed, fair reader, you did not, but some of you, perhaps your very self, indeed, did buy it to learn better how to learn easily; and one of the most essential things to be learned for this purpose is the utter incompatibility of learning and indolence. Were it otherwise learning would be of relatively little financial use, for every common millionaire would be a thinker, and each tramp a millionaire.

He who really *thinks* can never become conceited over his supposed learning. We may adopt the traditional colored preacher's attempt to make massive the idea of infinite despite its inconsistencies on close examination: Imagine a small bird hopping to and fro from Boston to San Francisco, carrying each trip a mouthful of water from the Atlantic into the Pacific Ocean; when the Atlantic at last was empty was this man's suggestion of an infinitely future time. So is human thought in comparison with the eternal miracle of Reality. But its eternal interest is a delight, and it grows with what it feeds upon. One's thought and imagination grows best when the mind is fresh, then the neurons are stimulated and actuated by the desire for activity. Sleep and play are essential, then, for thinking as in other things. In thought, more than in any other mode of action, the mind makes profit out of sudden gleams of light, out of inspirations; and play often stimulates the imagination and leads to the development of something new in thought.

The time of day in relation to the quality and the quantity of the work accomplished in thinking has much practical importance in the long run, and despite widely-varying personal habits of work and sleep and play the scientific status of the matter has worth-while practical interest. Professor W. H. Hack of the University of Virginia has studied the matter by grading the arithmetical reasoning of 255 girls and 212 boys (average age 14.2 years) in a grammar school. "The number of examples done in the afternoon was 0.68 per cent greater than in the morning; the per cent of examples right in the afternoon was 3.22 per cent less than in the morning." This result has been corroborated by like work done at Lynchburg and in New York. Thus we see that while the speed of such thinking in the afternoon is practically that of the forenoon, the accuracy is distinctly less. I have the impression derived both from personal experience and from sundry researches that the most productive hours in the whole twenty-four, qualitatively and quantitatively together, are the hours from 10.30 A. M. to 12.30 P. M. Then certainly the quality is at its highest, and this is true of creative work—thought in its broadest sense.

For the integration of one's thinking in a broad way and for making one's opinions and ideas at once more coherent, more intensive, and more conscious, no method exceeds in usefulness that of *writing definite articles* or papers with some topic-title not too narrow. This obviously for learning purposes is the often-hated "composition" of our early school-life—hated oftentimes just because its writing involved the completion of a certain definite amount of *real mental activity in a definite time.* This is a kind of debt to one's education which may not be, like Micawber's note-debts, paid always with other notes, other promises to do. Writing, as Francis Bacon reminds us, "maketh an exact man," but writing, too, makes a boy or girl, as well as a man, not only consciously aware of what is known and thought in his more or less hidden mind, but makes that more precise and its relations round about more real, and also more numerous. In other words, *writing much on set topics, not too narrow, clarifies and extends also one's ideas and makes them also more dynamic.* Nothing else, unless it be active oral debate, can do this either so economically or so well.

Corrosion of Iron.—Discussing the corrosion of iron K. P. Gregorowich, in *Rev. Soc. russe de Metall,* considers three different theories (1) based on the action of carbonic acid; (2) based on the formation of hydrogen peroxide; (3) based on the theory of electrolytic action, and he gives the preference to the latter theory. Study of the effect of the contact with metals whose potential is lower than that of iron, such as platinum, copper, nickel, lead and tin, shows that these materials increase the rate of corrosion.

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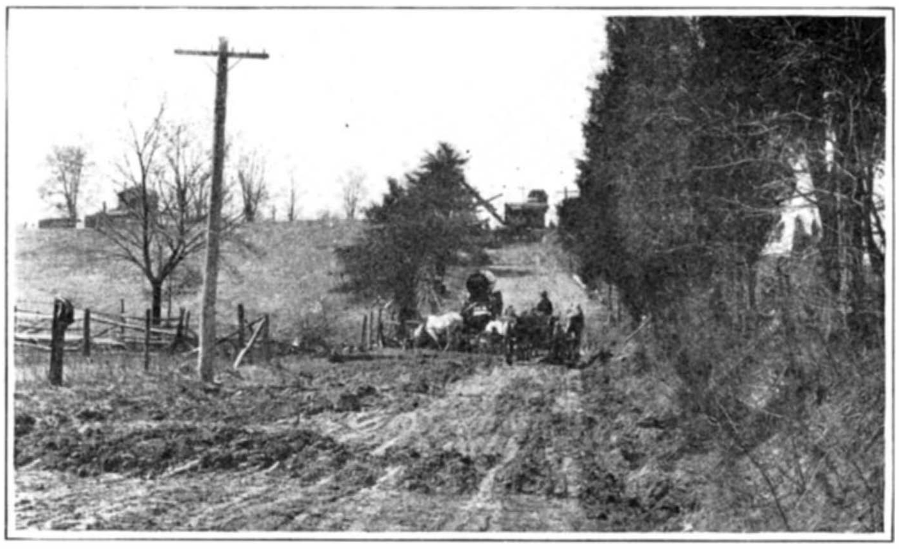
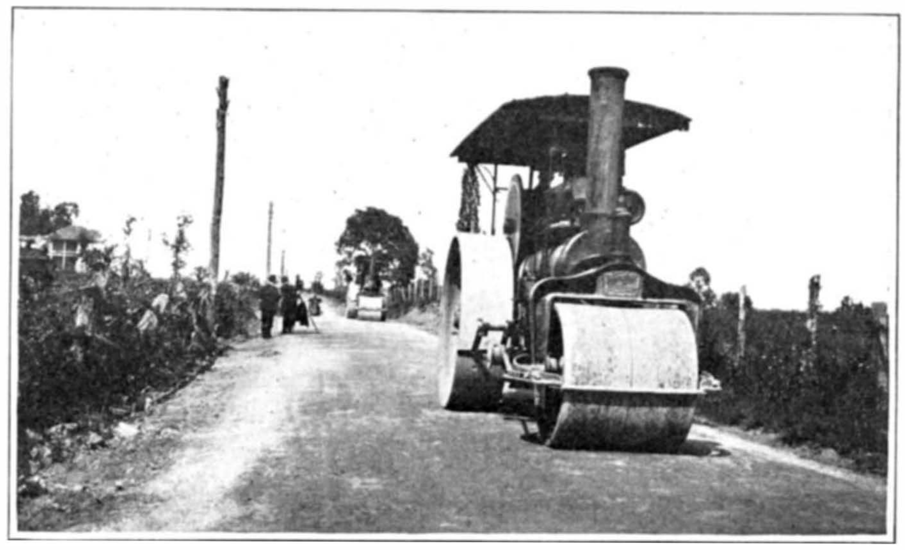


Grading an old road with a steam shovel.



Rolling in screenings after final sprinkling.

Good Roads and the Automobile

Various Methods of Construction and the Material Employed

By A. M. Jungmann

THE first essential to the enjoyment of motoring is a good road. The best car in the world will not give us much satisfaction if run over a badly graded, rutty, dusty, muddy or stony road as will a "flivver" on a good road. That is why the automobile has awakened the United States to the need of better roads.

During the year 1914 this country made greater progress in road building than ever before. Altogether the United States spent $225,000,000 on roads in 1914, and actually constructed 18,000 miles of new hard-surfaced roads. When the figures for 1915 are available, in all probability, they will indicate a still greater progress in road construction, maintenance and repairs.

In the majority of the States the fees for automobile registration are applied to the road funds, but not so in Alabama, Delaware, Minnesota, Tennessee, Texas, Washington, West Virginia and South Carolina with the exception of Oconee County. In South Carolina no definite provision is made for the distribution of the funds collected from automobile registration except in Oconee County, where the proceeds of registering motor vehicles go into the general road fund of the county. Texas does not provide for the distribution of the revenue collected from motors. It apparently goes to the county clerk who makes the registration.

As a general rule the states which apply the registration revenue to roads divide it equally between the State and the county in which it is collected. In Florida the registration revenues are paid into the county treasury and applied to the road and bridge fund of the county in which they are collected. Georgia apportions her registration revenues to counties in proportion to the number of miles of the rural mail route. The county commissioners of Georgia must actually measure the rural mail routes, and any county which is found misrepresenting the facts forfeits its right to share in the distribution for one year. New Mexico credits the registration revenue to the State highway fund and gives preference for its expenditure on automobile routes.

After construction the great road problem is that of maintenance, and maintenance should not be confused with good repairs. Properly maintained a well-constructed road requires practically no repairs. A road kept under observation so that constant attention is given to minor defects cannot get into a condition demanding actual repair except wherein work may be required on bridges, culverts or the renewal of shoulders after heavy rains.

Once in about six years a macadam road will require repair, which in this instance means resurfacing. A macadam road will gradually wear thin and finally become full of chuck holes. When it gets to the point where patching and repairs will not suffice to maintain it, resurfacing is desirable.

The macadam road suffers from automobile traffic because it depends upon the dust produced by traffic for its bond. As long as this dust remains upon the road and is washed into the interstices by the rains, the road keeps in good condition. But the days of such traffic have nearly passed, and automobile tires act very differently from the tires of the old-time horse-drawn vehicles. Pneumatic tires do not create dust, but raise what there is on the surface of the road, and it is blown away. Thus deprived of its natural binder, the macadam road surface deteriorates rapidly.

In resurfacing macadam roads it has been found desirable to employ some form of bituminous construction. The worn surface is first picked up or scarified and then the necessary amount of new stone is added. Stone varying in diameter from 1¼ to ½ inch is thoroughly mixed with a sufficient quantity of bituminous material to coat all the pieces. It requires about 1½ gallons of bituminous material per square yard of finished surface, so that if a second course were spread

Spreading No. 1 course of stone.

3 inches thick, loose, a cubic yard of stone would need 18 gallons of the bituminous material. After the mixture has been spread upon the road a thin layer of sharp, fine stone is evenly spread over the surface, and the whole is then rolled. It is essential to have the layer of fines made of clean stone from which all dust has been removed. When the rolling is completed the road surface is well swept, to removve all superfluous material. Then comes the final coating of bituminous material to make the road waterproof and insure the complete filling of the interstices. This final

Sweeping second course of screenings.

coating consists of about ½ gallon of bituminous material to the square yard of surface. Care is taken to spread it evenly.

The bituminous method of treating macadam roads prevents the loss of dust caused by the rubber tires of motor vehicles and protects persons living by the roadside from the clouds of dust raised by automobiles where the road is dependent upon water for binding material.

The question of dust preventives is one which road experts find of great importance. Water immediately presents itself to the mind as the natural dust preventive. The great objections to it for use on roads carrying a heavy motor traffic are that its effect is only temporary and that it is too expensive. The cost of continual sprinkling during a protracted dry spell soon mounts up.

In localities where sea water is available the cost of sprinkling is not as great as where fresh water must be employed, for the reason that sea water contains magnesium and calcium salts, which retain moisture to such a degree that it is unnecessary to sprinkle as frequently as it is with fresh water But sea water has a quality which makes its use objectionable. It contains much common salt, and in wet weather the mud is so salty that it damages both the iron work and the paint of the vehicles which pass through it.

A dust preventive which has all of the good and none of the bad properties of sea water is calcium chloride. This is a by-product obtained in the manufacture of soda. It is prepared for road use in a fine granular form and is inexpensive in cost. A thin layer is spread upon the road surface, and this rapidly absorbs moisture from the atmosphere. If it is used where the air is dry, the material may be kept moist by sprinkling it very lightly at infrequent intervals.

There are a number of other binding materials which have been used satisfactorily. One which seems to have been very useful in the neighborhood of sugar refineries is waste molasses, sometimes called "black strap." This combined with milk of lime forms a tough substance which is little affected by water. The binding effect is brought about by the action of the lime on the sugar in the molasses which forms calcium sucrates. If this material turns out to be as satisfactory as experiments would indicate it will undoubtedly be used freely in those districts where it can be obtained at a low cost.

Another binder is a concentrated waste sulphite liquor obtained in the manufacture of paper from wood pulp. This has been used with good results on macadam roads, but, as it is soluble in water, the roads must be treated frequently.

Non-asphaltic petroleum preparations have been found very successful on macadam roads. They hold the fine particles of dust together and prevent premature raveling of the road surface. Petroleum, coal tars, water gas tars and other bituminous products have been found to be excellent dust preventives. Since the advisability of using them in the refined rather than the crude state has been understood very satisfactory results have been obtained. The usual method of treating the petroleum products is to prepare an emulsion with cheap soap. These emulsified oils can be mixed with water and applied to the road surface by means of an ordinary sprinkling cart.

It is highly essential when applying any dust preventive to have the road surface well cleaned and free from dust if the best results are to be obtained. Wherever possible it is well to close the road to traffic 10 or 12 hours following the application in order to allow it to soak in thoroughly. A clean road, a light coat of material and time for it to penetrate the surface will achieve the best results.

In point of mileage the humble earth road is of the

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greatest importance in the United States. Out of 2,200,000 miles of roads 2,000,000 miles are earth roads, and there is no good reason why earth roads should not give satisfactory service if proper attention is paid to their drainage, grading, alignment and surface.

First and foremost should be considered the matter of drainage. The surface drainage should be cared for by broad, shallow ditches, which are provided with ample outlets. Of course, the road must be firm and even. There are a number of methods for accomplishing sub-drainage, such as blind drainage, French drains, sub-side-drains, center sub-drains, V-shaped drains and rock bottoming. One well-laid side-drain on the uphill side of the road should be sufficient. It is of the greatest importance that ground water be intercepted and so drained that the water will flow away from the road. Sub-drainage put in properly should be permanent. If carefully done with an engineer's lines and grades it should not be necessary to alter the drainage of an earth road should that road be improved by macadamizing.

After rolling the fourth course of screenings.

The solution of the entire road problem lies in maintenance. The ideal system is that which provides for the continuous employment of men who are familiar with road building and upkeep. Men who make their life job that of road making are sure to develop a pride in their work which teaches them to become sensible of their mistakes of one year and to avoid them the next. If each county could afford to keep several road laborers and one or two teams continuously employed on the roads, a big step forward in road maintenance would be made. In districts where the country is well populated and where the roads carry heavy motor traffic it should be possible to maintain a sufficient corps of road workers the year around to keep the roads in good condition. Such a system does away with extensive repairs and is, in the end, of the greatest value to a community. By all means let us strive to obtain continuous road maintenance rather than sporadic repairs.

The Transmission of Electric Energy From Sweden to Denmark

The transmission to Denmark of electric energy generated in Sweden is now an accomplished fact, and during the few weeks which have passed since it came into operation the system has worked quite satisfactorily. Although this is the first instance of the transmission of electric power from one country to another by submarine cables, current is transmitted across land frontiers in several localities. Thus a considerable district round Nancy, Toul and Verdun receives, or used to receive, electric energy from a colliery power station in German Lorraine; the hydroelectric power station at Rheinfelden, in Switzerland, supplies large quantities of electric energy to Germany; and Switzerland also supplies a considerable amount of energy to Italy; a Silesian colliery power station transmits part of its current to Austria; and there may be other instances of international electric supply.

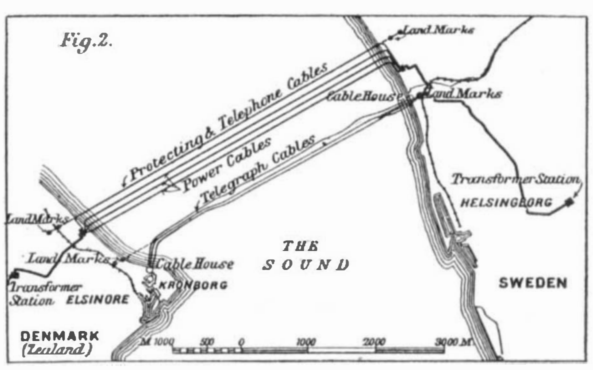
Electric energy is transmitted to Zealand by the South Swedish Power Company, which was formed in the year 1906 for the exploitation of the falls in the Lagan. This company now owns four power stations on the Lagan—one at Majenfors, one at Basalt, and two at Knäred—with an aggregate capacity of about 26,000 horse-power, or about 19,000 kilowatts. The annual production is at present 50,000,000 to 60,000,000 kilowatt-hours. As this power is almost completely utilized, extensions are about to be made in different directions. Three additional waterfalls have been secured in the Lagan, representing an aggregate of 10,000 horse-power, or 7,000 kilowatts. Further, a steam plant, with a capacity of 5,000 kilowatts, is being built in Malmö, and an arrangement has been entered into with the Höganäs-Billesholm Coal Mining Company for the supply of 2,000 kilowatts, and later on of 7,000 kilowatts, to be generated in a steam plant at Ormastorp, where some of the company's inferior coal will be used for fuel. The South Swedish Power Company will thus have about 40,000 kilowatts available in the near future.

The energy generated at the Lagan power stations is transmitted as three-phase alternating current at 50,000 volts to the different centers of consumption by means of copper lines on iron poles. The main lines to the more important places are in duplicate. The locality of the distribution system in Sweden and Denmark will appear from the map of Zealand and part of Southern Sweden (Fig. 1) which we publish on this page. The distance between Halmstad, in the north, and Trelleborg, in the south, is about 150 kilometers (93 miles). The current is transformed down from 50,000 volts to a lower distribution voltage—viz., 5,000 volts in the towns and 20,000 volts in the country. The more important towns included in the system are Halmstad, Engelholm, Helsingborg, Landskrona, Lund, Malmö, and Trelleborg.

Helsingborg, which is of special interest in connection with the Swedish-Danish electric supply, obtains its current from two 50,000-volt lines proceeding from the substation at Mörarp, where they are connected with the main line between Knäred and Malmö; the distance between these two places is about 60 kilometers (37 miles), and that between Mörarp and Helsingborg about 15 kilometers (9.3 miles). The supply to Denmark is taken from the Helsingborg transformer station, which has been enlarged for the purpose. The voltage is transformed down to 25,000 volts, which was deemed to be the highest pressure suitable for a cable installation of this nature. The current is transmitted at this pressure through the town of Helsingborg by two underground cables, 4.8 kilometers (3 miles) long, to Palsjö, north of the town, on the Sound, and thence, through two submarine cables, 5.4 kilometers (3.35 miles) long, under the Sound, to Marienlyst, on the Danish coast, north of Elsinore, and then through underground cables, 1.5 kilometer (0.93 mile) long, to a transformer station west of Elsinore. There the energy is transformed up to 50,000 volts, and transmitted through two three-phase copper overhead lines, supported on iron poles, to Gentafte, a further distance of 35 kilometers (21½ miles). The current is there transformed down to 10,000 volts, which is the normal distributing pressure of the North Zealand Electric Company. Some four or five feeding lines are here connected with the company's existing lines, so that the supply can be maintained from this station, and the Skovshoved plant be shut down. Part of the current will be transformed down to 10,000 volts at the Elsinore transformer station, so that the northern part of Zealand can be supplied direct from there. The overhead lines are protected by earth connected lines above the transmission lines, and the transformer stations are also protected against lightning. The cable lines from Sweden to Denmark, and the overhead lines on both sides, are in duplicate throughout, and either line is capable of transmitting the entire supply should the other become faulty. The maximum supply is calculated at 5,000 kilowatts, but should a larger supply be decided upon at a future date, a third cable will be laid, and the necessary extensions undertaken on shore. In order to protect the high voltage submarine cables from dragging anchors of vessels drifting south, a protecting cable has been laid parallel with the power cables, consisting of a steel wire rope with a breaking strength of 40 tons. This protecting cable also carries telephone cables for communication between the transformer stations on either side. The cable installation is shown on the accompanying map, Fig. 2, in its complete state, with three high-voltage cables and one protecting cable, all laid at a distance of 100 meters (109 yards) apart. The position of the cables was chosen so as to place them parallel with the State telegraph cables, the distance between the two being 600 meters (650 yards). To notify vessels that they are not allowed to anchor in the vicinity of the cables, land-marks have been erected on both sides of the Sound to show the position of the protecting cable. The land-marks consist of iron towers of trellis work, 25 meters (82 feet) high, with bases measuring 4 meters by 6 meters (13 feet by 20 feet). They are covered with wood painted white, and at night are illuminated with green lights. The submarine cables are insulated for 35,000 volts, or 10,000 volts more than they will be subjected to. In both submarine and land cables the sectional area of each of the three copper conductors is 70 square millimeters (0.109 square inch). The insulation consists of impregnated paper, and moisture is kept out by a lead covering outside the insulation. The thickness of the insulation is 11 millimeters (0.43 inch) in the land cables and 13 millimeters (0.51 inch) in the submarine cables. These thicknesses of insulation are provided between the conductors themselves and also between the conductors and the lead covering. The land cables are, as usual, protected by iron sheathing, and have an outer diameter of 78 millimeters (about 3 inches); their weight is 17 kilogrammes per meter, or 34 pounds per yard. The submarine cables are strengthened with galvanized Z-shaped iron wires, 6 millimeters (0.236 inch) in thickness; the outside diameter is 92 millimeters (3.6 inches), and the weight about 28 kilogrammes per meter, or, say, 56 pounds per yard. The submarine cable was supplied in nine lengths, of 600 millimeters (656 yards) each. The cable lengths are connected by means of iron coupling boxes 1½ meters (nearly 5 feet) long, by which the strain from the sheathing wires of the cables is transmitted. The connecting boxes have inner boxes of lead, which are soldered to the lead covering of the cables. Both boxes were filled with compound. After the joint was completed the iron boxes were asphalted outside, and all the outside bolt heads were covered with a zinc sheathing and asphalted. The protecting cable was supplied in one length of 5,400 meters (5,900 yards). The telephone lines are insulated with gutta percha; the outside diameter of this cable is 52 millimeters (2 inches), and its weight is 9.5 kilogrammes per meter, or 19 pounds per yard. The cables are laid direct on the bottom of the sea without any protection, but the shore ends are protected by steel tubes, and buried in the ground as far as possible, so as to protect them from wave action. On the Danish side the cables are laid in a dredged channel as far as the Lappen ground, where the water is shallow, and where, under unfavorable conditions of weather, numerous small sailing vessels are accustomed to anchor. The greatest depth at which the cables are laid is about 38 meters, nearly 21 fathoms.

Fig.1.

Fig.2.



As this submarine cable installation is entirely novel, and is liable to disturbance by anchors and storms, only one high voltage cable, the central one of the three, has been laid at present, in addition to the protecting cable; neither has the 50,000-volt overhead line from Elsinore to Gentafte yet been constructed. When in the course of some two or three years the working has proved satisfactory, the further installation will be proceeded with; in the meantime there will always be a steam plant in reserve on the Danish side.—*Engineering.*

The Use of Oak in France

In the early days of the United States oak was employed to some extent for the frames of buildings, and also for furniture, but the demands of shipbuilding and certain lines of manufactures so exhausted the supplies of this wood in the eastern country that it is many years since it was used in buildings, except for expensive interior trimmings. In France, however, oak is a favorite material for all kinds of building work and for furniture, and even the clapboards for the exterior of houses are frequently cut from it. This popularity of oak is probably due to the fact that at least two fifths of the forests of France, amounting to 10,000,000 acres, are oak.

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The "Noble" Gases*

How the "Nitrogen" of a Generation Ago Has Been Made to Yield Other Elements of Value to Chemistry

By Henry P. Talbot

From the earliest days of quantitative chemical experimentation the atmosphere has been the subject of frequent investigation. The discovery of oxygen as a separate entity resulted from the independent researches of Priestly in England and Scheele in Sweden about 1774, and nitrogen had been recognized as a new gaseous substance by Rutherford in 1772. The part which these two gases play in the atmosphere was demonstrated a little later, and for more than a century the literature contains innumerable records of physical and chemical measurements based upon the assumption that these two elements constitute the sole essential constituents of the gaseous envelope of the earth. Other substances, such as moisture, ammonia, and carbon dioxide, are, to be sure, universally present, but are accidental components, varying in amount according to local conditions, while oxygen and nitrogen are to be found in approximately constant proportions, no matter where the specimens of air may be collected.

Such was the universal belief when, in 1893, Lord Rayleigh, an English physicist, undertook to review the measurements of some of the natural constants of the more common permanent gases, among them the density of nitrogen gas. He was profoundly astonished to discover that "nitrogen" obtained from the atmosphere after removal of the other constituents, according to the then accepted methods, was distinctly heavier, volume for volume, than nitrogen obtained from the decomposition of chemical compounds of which it is a component. The differences were much too large to be accounted for by errors in manipulation or observation, since these were accurate to about one part in ten thousand, while the discrepancies in weight were of the order of one part in two thousand.

When this announcement was made public, speculation as to the cause of the observed difference in density was rife, but it soon became highly probably that a search must be made for a new element in "atmospheric nitrogen," as the residual gas which remains after the removal of the other constituents from the atmosphere is now called. To this search Lord Rayleigh and Prof. (now Sir William) Ramsay addressed themselves.

The first employed a method which was a repetition of work done nearly a century before by Cavendish. An electric discharge was passed through air in the presence of an alkali. This causes the oxygen to combine with a part of the nitrogen and the products of the combustion are absorbed by the alkali. In this way the oxygen can be removed, and the residue is "atmospheric nitrogen." Nitrogen is a comparatively inactive element in a chemical sense, but it can be made to combine directly with certain of the metals, such as magnesium, and by repeatedly passing the residual gas over the metal until no more diminution in volume occurred, they obtained a small quantity of a gas which was twenty times as heavy as hydrogen (taken as a standard) whereas nitrogen is only fourteen times as heavy. This final residual gas was found to amount to a little less than one per cent by volume of the original air. These results were confirmed by other and different procedures, and in 1895 the two co-workers felt justified in announcing the discovery of a new element, to which they gave the name argon, the inert; a name which later investigation has justified, since argon has resisted all attempts of the most varied character to induce it to enter into chemical combination with any of the other elements.

It is interesting to note that Cavendish just missed the discovery of this element, for in the record of his experiments we find that, when sparking a mixture of nitrogen with an excess of oxygen, he obtained a residue of which he says: "If there is any part of the phlogisticated air (now called nitrogen) of our atmosphere which differs from the rest and cannot be reduced to nitrous acid, we may safely conclude that it is not more than one one hundred and twentieth of the whole." The residue was undoubtedly argon, and it is remarkable that this record should have passed unnoticed for more than a century.

The chemist conceives that any given element is not indefinitely subdivisible by chemical agencies. He terms the ultimate particles atoms and further conceives that compounds are formed by the union of atoms of different elements. It is not possible to determine with accuracy the absolute weights of these atoms in terms of any units of weight in common use, but it is possible to determine the relative weights of the atoms of different elements, in terms of the weight of the atom of hydrogen taken as a standard. When a new element is discovered, almost the first concern of the chemist is to fix a value for its atomic weight on this hydrogen scale. Although argon, as already stated, forms no chemical compounds, it was found possible from its physical constants to fix upon a value for its atomic weight with much probability of truth. But a fresh difficulty then presented itself, namely, that this new element did not fit into the so-called periodic system of the elements. Mendelejeff has found that, if the known elements are arranged in the order of their atomic weights, those elements which have generally similar properties recur periodically in the resulting system. But argon, with an atomic weight 40, which was the value found for it, would be out of place; that is, it would be associated in the system with very dissimilar elements. Since repeated determinations of the atomic weight made upon different specimens of the gas confirmed the figures first obtained, and since, according to the periodic system, the value seemed to be too large, a search was begun for possible small admixtures with the argon of a second new element with larger atomic weight.

At this time it was recalled that nitrogen had been found in the gases occluded in certain minerals, and it was suggested that argon might also be found in these gases. Prof. Ramsay collected a considerable quantity of the gases from a mineral called cleveite, and these did contain argon, but they also yielded another new element, although not the one for which they were searching. In this discovery the spectroscope played the principal part. It is known that highly heated gases give out light which when examined with the aid of a prism is found to be different from sunlight, in that it does not produce a continuous spectrum. The heated gases emit light of certain definite wave-lengths, which appear as bright lines in different parts of the spectrum. These lines can be charted with great exactness and have a constant position for a given element. Sir William Crookes, who made the spectroscopic examination of the gases from cleveite, reported the presence of an element yielding lines identical with those shown in the spectrum of the sun's chromosphere during an eclipse, and ascribed as far back as 1868, by Lockyer, to an element which he called helium. Later measurements confirmed the identity of the lines in the spectrum of the new gas with those of helium, and density determinations showed that this element has an atomic weight of 4 on the scale indicated above. It could not, therefore, account for the discrepancy in the atomic weight of argon, but its discovery clearly pointed to the existence of other elements of the general character of argon. It should be noted in passing that the similarity of the spectra of argon and nitrogen, as well as its inert character, largely accounts for the failure to detect its presence in the atmosphere for so long a time.

Thus stimulated, the search for other inactive elements was continued. A considerable quantity of argon from the atmosphere had been laboriously collected, and preparations were made to liquefy it and subject the liquid to fractional distillation, that is, to allow it to evaporate slowly, collecting the gases evolved in separate portions or "fractions," the first of which would contain a larger proportion of that element which boiled away most readily, just as alcohol tends to boil away first from a mixture of alcohol and water in the radiator of an automobile. These "fractions" were then separately liquefied, and each, in turn, refractionated, in this way gradually separating the more volatile from the less volatile constituents. The same procedure was applied to the residues obtained upon the evaporation of liquid air. Indeed, without the use of liquid air, and liquid hydrogen, as refrigerating agents, or the skill in manipulation of liquefied gases obtained through the handling of liquid air, together with the perfection of the evacuated double-walled Dewar flasks, the isolation of the different inert gases would not have been possible.

The separation by means of fractional distillation had to be supplemented by other physical methods, namely atmolysis, or diffusion through minute openings; and later, the adsorption of gases in the pores of willow-charcoal at low temperatures. The less the density of a gas the more readily it diffuses, hence by passing a mixture of gases of different densities through something like the stem of a clay pipe, the lighter gas is made to pass through the pores at a more rapid rate than the others and may be collected from the outside.

By combinations of these three procedures, fractional distillation, diffusion, and selective adsorption in charcoal, it has been possible to isolate and identify five members of this wholly unique group of gases, often called the "noble gases" because of their apparent disinclination to associate themselves with other elements. The elements are helium, neon, argon, krypton, and xenon. The first two are lighter, the last two heavier, than argon. Nothwithstanding the discovery of the two latter elements, the anomalous position of argon in the periodic system is still unexplained, since they are not present in sufficient amounts to alter appreciably the atomic weight determination. The other members fit into the periodic system without difficulty.

A sixth member has recently been added to the group in the discovery of niton, the emanation given off by radium compounds in the first step of their disintegration. This has been obtained in amounts weighable only by specially constructed balances of remarkable accuracy, but, notwithstanding the great difficulties to be overcome, its atomic weight has been determined with probable accuracy, and its chemical inertness established. There is some reason for suspecting the existence of a seventh "noble gas," lighter than helium, which because of its small mass would not probably remain in the earth's atmosphere, but would be attracted by the larger heavenly bodies, and would even then probably be found only in the outer portions of their atmospheres. Spectral lines have been detected from the sun's corona, emitted by some substance outside the zone of hydrogen or helium, and these lines are not identical with those of any terrestrially known element. The name coronium has been tentatively assigned to this element—just as helium was named by Lockyer in 1868—and it may be another "noble" gas.

Five members of this group, helium, neon, argon, krypton and xenon, are found in the atmosphere, and niton is probably present in most minute amounts. The proportions of the other gases seem to be about as follows:

Helium, 1: 185,000; neon, 1: 55,000; argon, 1: 106.3; krypton, 1: 20,000,000; xenon, 1: 170,000,000.

Liquid air is the source of all of these gases to-day, except helium, which although present in liquid air is more readily obtained from the gases occluded in certain minerals, as noted already. Neon has offered the greatest difficulties in purification.

The discovery of a series of elements without any chemistry, such as had been unknown and possibly unimagined, was, of course, sufficient to excite great scientific interest, after a certain period of incredulity as to the validity of the discovery had passed. Their scientific importance is further enormously enhanced by the discovery that helium is a product of the disintegration of radioactive materials, and that all terrestrial helium probably owes its origin to this source. There is no direct evidence at present that any of the other inert gases, except niton, have a similar origin, but the final conclusion on this point has yet to be reached.

Helium remained unique for some time after its discovery as the only gas which it was impossible to liquefy. Even Dewar, so skilled in such methods, was unsuccessful, but Onnes, building upon the foundation laid by Dewar, has succeeded, and has produced liquid helium in considerable quantities. Its boiling-point is about 4 degrees above absolute zero, that is, about —269 deg. Cent., and Prof. Onnes has conducted a series of most valuable investigations upon the effect of this temperature (the lowest at our command) upon physical phenomena, notably electrical phenomena. One of the most striking results of his investigations is his demonstration that an electrical current induced in a lead ring placed in liquid helium continues to flow for a long time after the exciting cause is removed; that is, electrical resistance nearly disappears at that temperature. It is evident that this opens an immense field for experimentation and speculation.

Argon is now comparatively easily obtainable from liquid air, provided it is not necessary to purify it from the small amounts of the other inert gases, which do no harm in argon for technical purposes. It has already found commercial use in the "argon lamp," the successor of the nitrogen lamp. Formerly the bulbs of the tungsten lamps were evacuated as completely as possible, but it was subsequently found that if these lamps were filled with nitrogen at atmospheric pressure they could be run at a higher temperature and greater efficiency without too great evaporation of tungsten from the filaments. This is supposed to be due, in part, to

* From *Science Conspectus*.

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the collision of the molecules of tungsten as they leave the surface of the filament with those of nitrogen gas, which drives many of them back to the filament. Since argon has a heavier molecule than nitrogen, and is completely inert, it has been substituted in these lamps, with a resulting further increase in efficiency.

Krypton, notwithstanding the minute proportions in the atmosphere, is possibly intimately connected with the phenomena of "northern lights," since the spectrum of these lights shows the lines of krypton with considerable prominence.

From a scientific viewpoint niton is the most unusual of these elements, since it possesses two characteristics which were absolutely unknown in 1895, namely, complete chemical inactivity, and a temporary existence due to atomic disintegration, the discovery of which has given rise to a new primary science, radioactivity. Niton has already been used, in aqueous solution, as a curative agent in radiotherapy. The nature of the changes involved could not be made clear without a somewhat extensive presentation of radioactive phenomena in general.

Although of comparatively little practical value in themselves, the discovery of these noble gases, closely associated as two of them are known to be with the story of radium and its congeners, has had an enormous influence upon our present concepts in physics and chemistry which is daily bearing fruit. What the future may bring is beyond the compass of our imaginations, but new ground has been broken, which has permitted us to delve a little deeper into the foundations of scientific knowledge. Old concepts have been confirmed and broadened (very few destroyed) while vast unsuspected stores of energy in common matter have been revealed, which only our ignorance of to-day prevents us from using for the purposes of life.

Oils and Other Reagents in Flotation*

By Robert J. Anderson†

THE advent and application of the flotation process, as it is now understood by its more authoritative exponents, marks one of the most noteworthy and revolutionary advances in modern metallurgical endeavor. Flotation marks a new era in the concentration of ores and of intermediary mill products. Although the process was discovered some fifty-five years ago, it is only recently that mill men and others have come to a realization of its virtues and have applied its principles on a commercial scale. This tardy application of a process so long known must necessarily be ascribed to certain inherent difficulties, which were encountered and which could only be effaced by time. Since it is not so long ago that the process was uncertain of success, the rapid strides made in the last few years can be regarded as nothing short of remarkable. Recently flotation has demanded the attention of mine operators, mill men, and others interested in the mining and metallurgical welfare of the country, particularly the United States Bureau of Mines and the bureaus of experimental research in connection with the universities teaching mining and allied subjects.

Disregarding here the mention of the manifold number of patents which have been taken out for the flotation process, the subject of litigation, and the theories which have been advanced to explain the "why" of flotation, it may be safely stated that probably nothing relative to the application of flotation on a commercial scale has received the attention which the oils have. It is a well-known fact that virtually any kind of oil, grease, or oleic acid may be used in this process; the number of oils or rather combinations of oils which have been tried experimentally and commercially is almost without end.

This use of oils has given impetus to the production of wood creosotes and other wood fractions particularly in the South, the market for which had hitherto become rather stagnant; further, the increased production of coal tars and similar distillates in coke and gas manufacture has lately been more warranted; then, too, the petroleum industry has had a share in furnishing oils for flotation consumption.

To-day there are probably 200 flotation plants in active operation in this country, and this number is rapidly increasing as time proceeds. The flotation process will undoubtedly have a far-reaching application, but in no sense can it be looked upon as a universal panacea for all metallurgical ills. There can be little doubt that the process has come to stay, and probably its full significance is not even now realized. The metallurgical treatment of the concentrates produced in flotation presents an entirely new problem not hitherto encountered in metallurgical work and also a field for active research.

OILS IN FLOTATION.

There are so many oils available for use in flotation work that judicious selection has become a factor almost as important as the quality of an individual kind. In spite of the fact that considerable experimental work has been performed pertinent to the use and application of oils in flotation, there is a decided dearth of data regarding their effects and action. It is known, however, that certain oils, or rather combinations of oils, are applicable to the treatment of certain ores while others are only remotely so.

These oils, generally in mixtures of one sort or another, have been employed as flotation oils: namely, coal tar and fractions from the distillation of coal, such as coal creosotes; castor oil (mixed in small amount with kerosene or burning oil); eucalyptus oil; pine oil; pine tar; pine-tar oil; rosin and rosin oil (used for the residic acid therein); wood creasote and other products obtained in the destructive distillation of wood, such as pyroligneous acid; petroleum products of different kinds when mixed with a small proportion of the wood oils or some of the coal-tar products.

Although certain oils have all the inherent properties which would suggest their applicability as flotation oils, the fact that they are prohibitively costly must act as a strong deterrent either for their use or investigation.

In the United States the oils derived from the pitch pine have given the most satisfactory results on a commercial scale; whereas in Australia, which country is in the van in flotation to-day, the essential oil of eucalyptus has been the most successful. Recent commercial practice has shown that oils of mineral origin promote the best recovery in the case of copper ores, and that oils of vegetable origin, such as the pine oils, turpentines, wood tars, and creosotes, are conducive to the best recovery in the case of galena and zinciferous material.

Broadly stated, flotation oils may be classed as "frothing" oils and "collecting" oils. There is at times some difficulty in grasping the distinction between frothers and collectors as such, for one oil in itself may, and often does, possess both frothing and collecting properties. The action of a frothing oil is such as to produce froth in greater or less amount, dependent on the frothing power of the oil. A collecting oil has a collecting power for sulphides in preponderance over its frothing action, being therefore, so to speak, a poor frother; a collecting oil may have simply a collecting action and little or no frothing action. As stated in the foregoing, some oils combine both the properties of frothing and collecting in variable degrees of each. In the flotation parlance then, the classification is given: (1) Frothing oils; (2) collecting oils.

FROTHING OILS.

The most successful frothing oils include the pine oils, cresylic acid, and turpentines and other pyroligneous products from the distillation of wood—notably methyl alcohol. The coal tar phenols and their near derivatives, and almost or all of the so-called essential oils, are good frothers. The essential oil of eucalyptus finds favor, particularly in Australian practice, on account of relatively low cost and immediate supply. Castor oil, to which reference has already been made, when mixed 1:4 with kerosene has found application. The more volatile products of petroleum, including kerosene and gasoline, have been successful frothing oils.

On some ores crude pine tar combines the properties both of frothing and collecting; on other ores it is necessary to enrich the pine tar with some such oil as turpentine, pine oil, or wood creosote. Unquestionably, pine oil (steam refined or crude) is the best frothing agent known; however, generally the selective action is not positive and marked, and the concentrates will contain gangue in considerable amount. Experiments in this laboratory indicate that cresylic acid is particularly adapted to the flotation of zinciferous material, exhibiting both good frothing and selective properties.

COLLECTING OILS.

So-called mineral oils and tar oils do not generally form a good flotation froth, but have a marked selective action on the sulphide minerals. Among the mineral oils are included the following: asphaltum base, crude petroleum, refined oil, gasoline, burning oil, creosol and coal tar and coal-tar creosotes. Oils derived from the destructive distillation of wood, such as wood creosotes, pyroligneous acid, and the like, are found to give the best recovery on galena and zinciferous material; coal-tar products are better adapted to the successful flotation of copper bearing materials.

It is found that thick oils tend to form viscous, coherent flotation concentrates, while thin oils form less coherent masses. The action of coal tar in stiffening a weak, ephemeral froth is indicative of the former. In general the essential oils give a coherent froth and satisfactory extraction; oils like oleic acid or candle-maker's red oil, petroleum, and lubricating and engine oils have a strong tendency to produce heavy, thick granules which will not float. Oleic acid has a well-marked power to float silica.

OTHER REAGENTS IN FLOTATION.

The chemicals used in connection with oil flotation include the following: sulphuric acid, bichromates, permanganates, alkaline chlorides, alkaline sulphates and bisulphates, cupric sulphate, ferric sulphate, aluminium sulphate, thiosulphates and sulphites, organic electrolytes, such as tartrates, citrates, and citric acid, and others almost *ad infinitum*. Generally the purpose of other reagents than oils is to aid and abet a preferential flotation between the sulphide minerals or in some cases to effect a better separation of mixed sulphides from gangue material, unless indeed they be employed to counteract the deleterious action of certain soluble constituents in either the ore treated or in the water used, or both.

Recent commercial practice indicates that the use of sulphuric acid can be dispensed with if the proper oil combination can be found. Callow[1] very appropriately remarks that the same results can be obtained in an alkaline or neutral pulp as in an acid one. Many mills have come to the use of no acid or even to alkaline electrolyte; this latter promotes good recoveries in the treatment of pyrite as well as other minerals at times.

Experiments performed here on a 60-mesh product from the Joplin district containing pyrite and galena in a calcareous gangue show the following:

1. Potassium dichromate will deaden galena and permit the flotation of the pyrite—a true preferential flotation.

2. Alkaline sulphates, i. e., sodium and potassium sulphates, promote the production of clean concentrates; the same is true of ferric sulphate $Fe_2(SO_4)_3$.

3. Ferrous sulphate, $FeSO_4$, and cupric sulphate were very harmful to the successful flotation of this particular product, flotation being practically impossible in their presence.

From these results and others of the same nature it is seen that it is of cardinal importance to ascertain the nature of the soluble constituents of the ore and also the nature of the water used in the flotation; proper precautions must be taken if anything of a deleterious character is present.

There seems to be considerable weight in the statement "a particular oil for a particular ore." In other words, no given oil can generally be employed effectively on a number of different ores. Further, different samples of the same oil will produce radically different results, as a small variation in homogeneity often engenders considerable difficulties. Usually acid will produce a concentrate free from silica, but its use can probably be just as well avoided.

Sizing—Careful screen analysis with subsequent microscopic examination or wet analysis shows that in slimes, for instance, the bulk of the values obtain in the material that passes the finer meshings. And it is believed that the ordinary run of ores require grinding to 60-mesh at least for oil flotation treatment.

Microscopic Examination.—The microscope is an invaluable aid in flotation work of an experimental nature, effecting a large saving of time which would otherwise be consumed in tedious and long drawn-out quantitative analysis. Casual inspection under the microscope will give at once a pretty definite idea of the grade of the tailing, middling, or concentrate. Quantitative analysis is, of course, the final criterion on which to base results. The binocular microscope is more satisfactory than any other type.

Results of Experiments on a Settled Product from the Joplin District.—Additional experiments performed on the product mentioned above warrant these conclusions:

1. A satisfactory oil mixture would be: 5 parts wood creosote, 2 parts pine oil, 0.5 part coal tar; or part of the pine oil may be replaced by soap solution in variable amount, thus reducing the cost.

2. A pulp dilution of 3.5:1 or 3:1 works well; the general run of data indicate that the pulp could be run as thick as possible within limits which would be occasioned by the fouling of the operation due to clogging of the test machine.

3. The action of the coal tar here is to stiffen the froth which for any reason might become weak.

4. The effect of temperature was practically *nil*.

5. Sulphuric acid does not increase the tenor of the concentrates.

[1] Bull. A. I. M. E. Dec., 1915, p. 2321.

* *Metallurgical and Chemical Engineering.*

† Mine Experiment Station, Missouri School of Mines, Rolla, Missouri.

A Remarkable Soap Bubble

AT a recent meeting of the Royal Institution, London, Sir James Dewar exhibited a remarkable soap bubble that he had blown a month before, and which was still as perfect as when formed. It is described as a glowing sphere of iridescent color, showing no signs of "blackness," which is the prelude of collapse. The longevity of the bubble is described by Lord Rayleigh as a case of suspended gravitation, which is due to the fact that it was blown in and with clean air, free from motes or small particles of solids, which, so far as soap films are concerned, appear to be the seeds of decay.

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Progress in Arc Lamp Technology[*]

Advantages of the Newer Designs Compared With the Incandescant Filament

IMPROVEMENTS in the construction of arc lamps, which had remained in an almost stationary condition for some time, have recently been introduced to meet the competition of the new metallic filament incandescent lamps of high candle-power, in the illumination of large areas.

At first glance such competition seems hopeless, for while the most efficient metallic filament lamp, known as the half watt lamp, consumes 5 to 7 times the electric energy required for an arc lamp of the same candle-power, there are other factors to be considered. When the metallic filament lamp of 1000 candle-power and a life of 800 hours made its appearance, it was necessary to renew the carbons of the best arc lamps every second day,

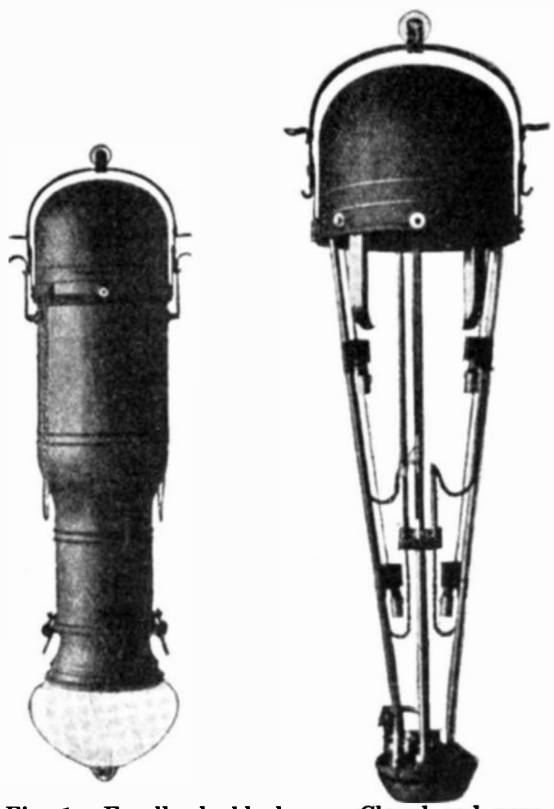

Fig. 1.—Excello double lamp. Closed and open.

and the great majority of arc lamps required still more frequent renewal. This great disadvantage of the arc lamp in regard to the cost of attendance has since been partly removed by the invention of arc lamps which burn without renewal for 30, 50 and even 100 hours.

An interesting representative of the new long-lived arc lamps is the Excello double lamp (Fig. 1), containing two pairs of carbon . which come into action successively and have an aggregate active life of 36 hours. The change from the first to the second pair is effected automatically when the first pair is almost entirely consumed, so that there is a great economy in carbons, in addition to the advantage that the carbons need to be renewed only once in two or three days in winter, and once in four or five days in spring and autumn. As the consumption of energy is only one fifth watt per candle-power, the total cost of operation and naintenance is 35 per cent less than that of an ordinary arc lamp.

The active life of an arc lamp can be prolonged, without using a second pair of carbons, by adopting the "effect" system of construction. The Dia Effect lamp (Fig. 2) burns 100 hours without attention. There would be little or no advantage in prolonging the active life still further, as the lamp would need cleaning after 100 hours of service.

The Dia lamp is provided with an automatic signal resembling a semaphore which indicates when the carbons need renewing. The time during which the lamp con-

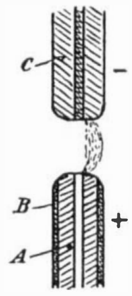

Fig. 3.—Crusta carbons.

tinues to burn after the fall of the signal can be adjusted to meet varying conditions of service.

Another advance in arc lamp technology is shown by the Crusta carbon for "effect" lamps, which has recently come into the market, and which is claimed to burn 40 to 50 hours on direct current with a consumption of only 0.14 watt per candle-power. The positive carbon (Fig. 3) is a hollow homogeneous arbon *A*, coated with a layer of light-producing salts *B*. The exact composition

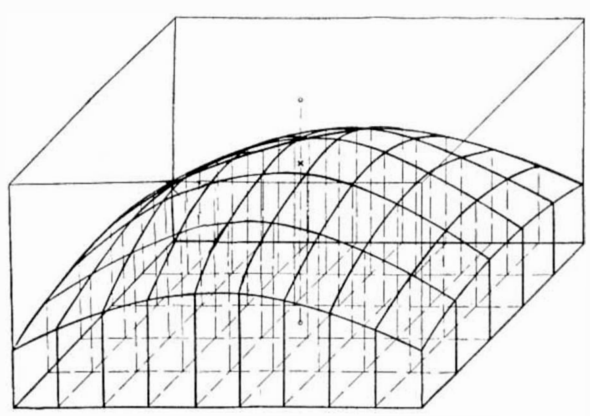

Fig. 7.—Diagram showing distribution of illumination in a room lighted indirectly by a single Nobi lamp.

of this coating has not been made public, but it is known to contain calcium fluoride, sodium tungstate and potassium chromate. The coating protects the carbon from the air, thus retarding combustion, and covers the end of the carbon with a crust which performs the functiou of a wick in drawing the salts upward to the luminons arc. The negative carbon *C* is a homogeneous cored carbon, with a core differing little in composition from the ordinary.

The improvements mentioned above apply chiefly to exterior illumination, in which field the arc lamp was already superior to the metallic lamp, as it produces stronger and more effective illumination with a smaller consumption of energy. The great reduction which these improvements have made in the cost of attendance destroys the only advantage which the metallic filament lamp possessed for exterior illumination.

The conditions are altogether different in interior lighting. Here the quality, the color of the light is important, and the whiteness of the arc light, which is very similar to daylight, gives it an advantage over the metallic

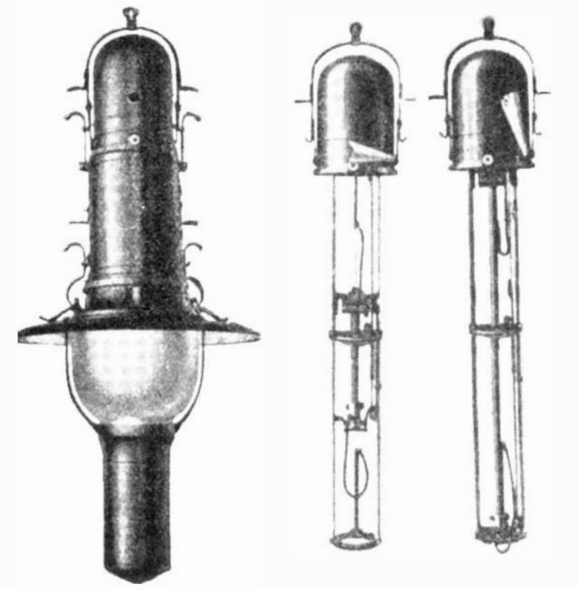

Fig. 2.—Dia "effect" lamp, closed and open, showing two positions of service signal.

filament lamp which gives a reddish yellow tint to all objects. Furthermore, it is easier to produce a diffused illumination free from glare with suitably constructed arc lamps than with incandescent filament lamps, which dazzle when they are inclosed in clear glass globes, and work uneconomically in ground glass globes, which, moreover, greatly diminish the illumination at a distance.

Recent improvements in arc lamps for interior lighting have been made chiefly in lamps for indirect illumination, in which field results have been obtained that seem to establish the superiority of the arc lamp, even for interior illumination.

One of the most successful of the new arc lamps for interior lighting is the Nobi lamp, three forms of which are herewith illustrated. Fig. 4 shows a lamp with carbons inverted, so that the positive and most luminous carbon is below and radiates its light upward to the white ceiling, which diffuses it through the room. In the lamp shown in Fig. 5 the carbons are in the usual position, but the radiation from the upper positive carbon is intercepted and thrown upward to the ceiling by a large

[*] Abstract of article by Werner Bergs in *Prometheus.*

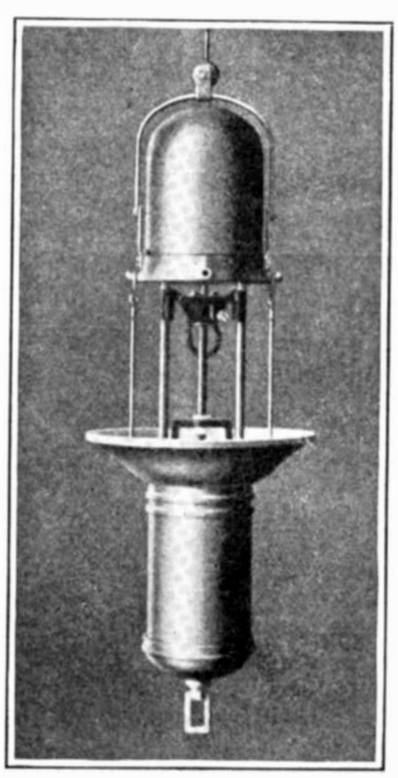

Fig. 4.—Nobi lamp with inverted carbons.

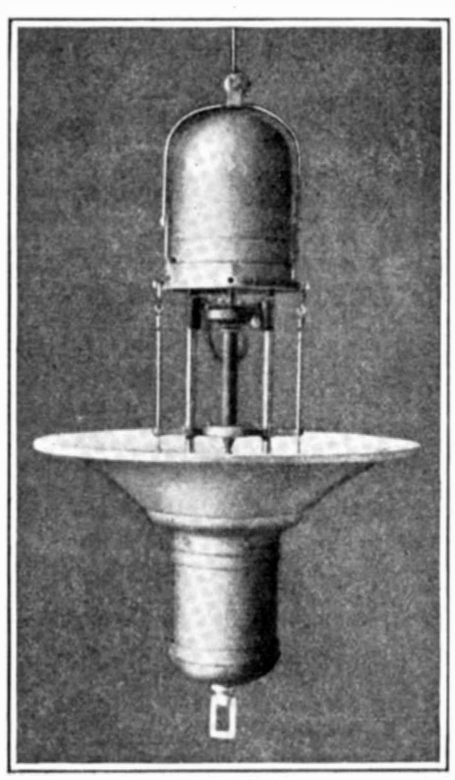

Fig. 5.—Nobi lamp with metal reflector.

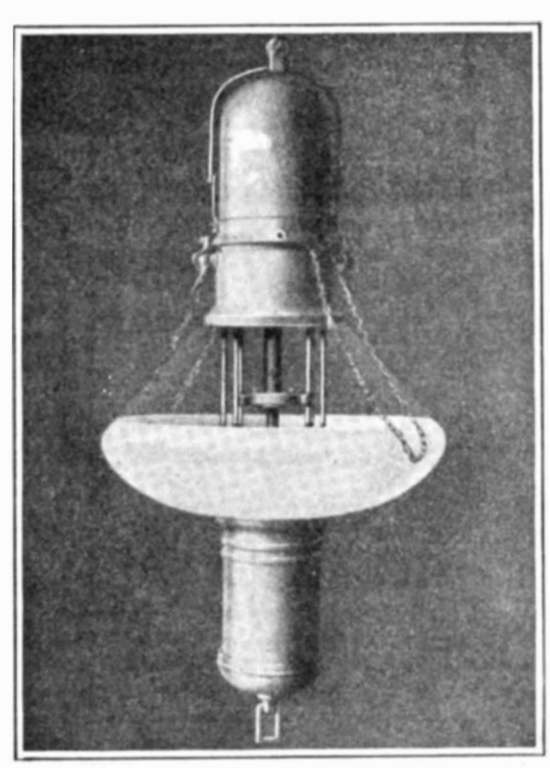

Fig. 6.—Nobi lamp with opal glass reflector.

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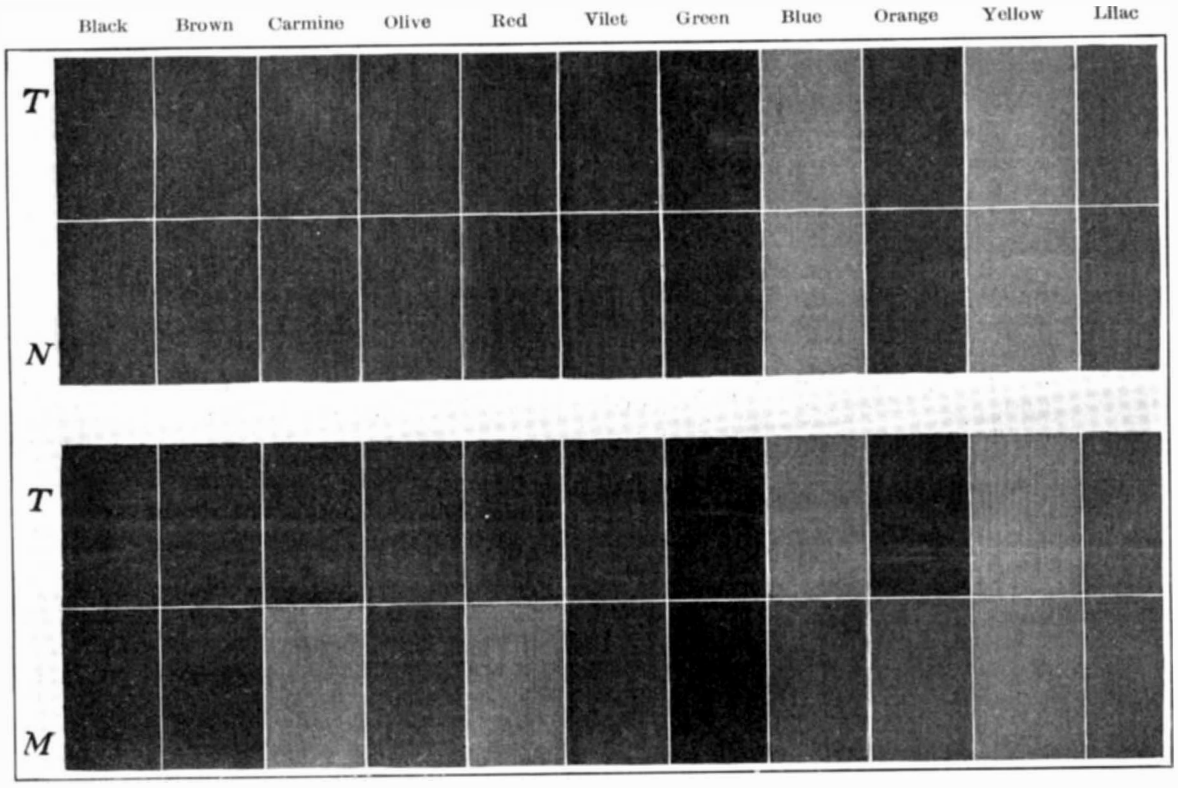


Fig. 8.—A series of colors photographed (T) by daylight; (M) by incandescent light; (N) by arc light.

metal reflector. In the third lamp (Fig. 6) the metal reflector is replaced by one of opal glass which diffuses part of the light downward.

The uniformity of the illumination produced by the Nobi lamp was tested by measuring the illumination, at 60 uniformly distributed points, 1 meter above the floor of a room 10 meters long, 6 meters wide and 5 meters high, lighted by a single lamp in the center, near the ceiling. In the diagram (Fig. 7), these points are represented by the feet of 60 vertical ordinates, whose heights are proportional to the corresponding intensities of illumination. A glance at the diagram shows that even the corners of the room were well illuminated.

The superiority of the arc light for the illumination of large interior spaces, especially shops and ball rooms, is made evident by Fig. 8, which shows the results obtained by photographing a series of colors by daylight (*T*), by the light of a metallic filament lamp (*M*), and by the light of a Nobi arc lamp (*N*). The daylight and arc light photographs are almost exactly alike, while in the incandescent light photograph the blues are too dark and the reds are too bright.

Mechanotherapy at Home

One of the commonest after-effects contingent on a fracture or a severe wound is stiffness of the joint, a disability which puts many soldiers out of commission even after recovery from the immediate injury. Mechanotherapy is one of the most effective means of ameliorating such troubles, but such treatment is costly, since few hospitals are fitted with the expensive apparatus required. In the emergency created by the number of such cases due to the war a well-known French physician, Dr. Privat, has devised a very simple, inexpensive and easily installed apparatus which can be used by such patients in their own homes.

This is shown in the accompanying diagram, for which we are indebted to *La Nature*, and is said to produce excellent results. "Upon the member to be restored to flexibility, the articular lever to be mobilized, as we say in medicine, there is exerted continuous traction perpendicular to its axis, by means of a

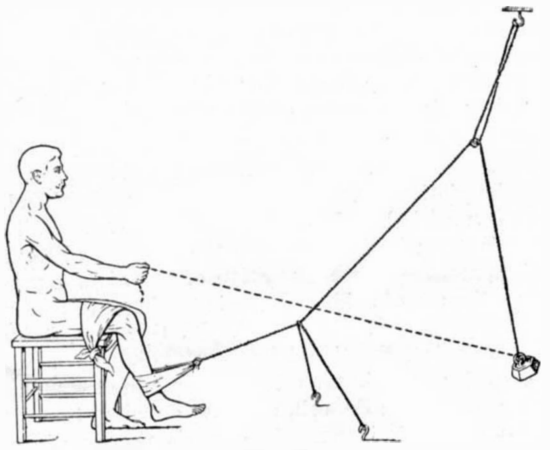


Fig. 6.

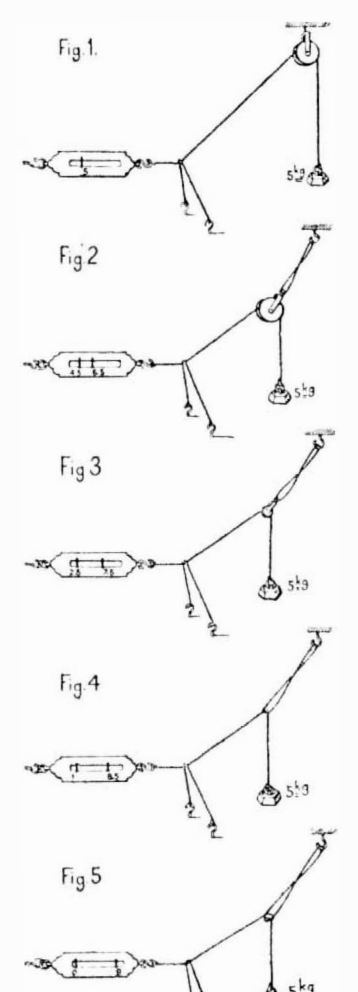
weight and a cord passing over a pulley, not fixed, but hung to a cord fastened to the ceiling. When the weight oscillates it produces, in a very gentle and rhythmic manner, tractions passing progressively from a maximum to a minimum and inversely.

"To utilize the apparatus it suffices to (*sic*) immobilize the articular lever by means of a napkin folded scarf-wise, and to direct the traction by causing it to pass underneath a cord whose extremities are fastened either in the floor or above the head of the patient. By pulling and relaxing a cord fastened to the weight the patient can maintain the oscillations. Moreover, the apparatus can be graduated, which is advantageous, since the articulations do not all have the same sensibility. To accomplish this all that is necessary is to use pulleys of different diameter, which, by employing the same weight as a motor, e. g., 5 kilogrammes, permit one to obtain the combinations shown.

EXPLANATION OF DIAGRAMS.

Fig. 1.—*Continuous traction apparatus.*—The pulley is fixed to the ceiling. When the weight oscillates, the dynamometer indicates merely imperceptible variations.

Fig. 2.—*Mecanotherapic apparatus.*—The pulley is



hooked to a cord hanging from the ceiling; the dynamometer registers different values corresponding to the different times of the movement of the weight.

Fig. 3.—The oscillations of the dynamometer augment in amplitude as the diameter of the pulley diminishes.

Fig. 4.—The pulley is omitted and the traction cord rests directly in a loop formed by the suspension cord. The needle of the dynamometer indicates oscillations considerably greater than in the preceding case.

Fig. 5.—The traction cord is knotted around the suspension loop. The dynamometer needle indicates oscillations still greater and even passes the limit of the scale.

Fig. 6.—The patient maintains the oscillations of the weight by pulling and relaxing a cord attached directly to the weight.

Polishing Metal With Clay

Experiments have proved that for polishing metals, and particularly for polishing the sections or slices of metals used in metallography, pure clay is much better than the ordinary polishing materials, such as tripoli, Vienna chalk, wood charcoal, and red iron oxide (English red). For example, a given piece of metal can be polished with clay in one-fourth the time required with iron oxide, and one-fifth the polishing material. This excellence, however, belongs to the clay only when it is exceedingly pure, and especially prepared for the intended purpose.

Such a product is prepared, according to *Prometheus*, in a metallographic plant in Düsseldorf in the following manner:

The crude clay obtained by burning ammonia alum is ground for a whole day in a ball-mill, in order to reduce as large a percentage of it as possible to the greatest attainable fineness. The powder thus obtained is not, however, sufficiently fine for polishing. It must first be freed by chemical means from such foreign substances as it contains and then thoroughly washed with distilled water. This purification, which may require as much as 10 days' time, is followed by a separation process in which the clay powder is divided into grades according to its degree of fineness. The degree of fineness is determined by repeated examinations with the microscope during the separation process.

The part of the clay which is first separated out is hardly fine enough to be used as polishing material, since the granules of which it consists are comparatively large, hard, and irregular, i. e. those which have proved most resistant to the action of the ball-mill. The portion of the clay which is found deposited at the end of three hours is, however, fine enough to be used as a polish, especially for steel and other hard metals. It grips the metal very rapidly and powerfully and therefore permits rapid action by the polishing wheel. However, it may occasion fine scratches, though these are not large enough to be seen by the naked eye, and are therefore usually unimportant.

The grain of the clay deposited at the end of 12 hours is far finer and more regular; however, it grips the metal more slowly, and therefore operates less rapidly than the three-hour clay. Since it produces a mirror-like polish on hard and medium-hard metals, it is specially suited for polishing brass, bronze and other copper alloys, or nickel alloys.

Still finer, naturally, is the granulation of the clay deposited at the end of 24 hours. This is suitable for working with soft metals, but is much slower of action than the two preceding powders. This polishing clay is offered suspended in gas-flasks in distilled water. When it is to be used this liquid is thinned by mixing it with water to which about 2 drops of nitric acid have been added. From 10.5 to 8 grammes of the liquid, according to the fineness, are added to 500 grammes of water, and the diluted liquid is sprinkled on the polishing surface. In order to avoid a mixing of the three grades of clay they are tinted with a neutral dye; blue for the three-hour deposit, white for the twelve-hour deposit, and red for the twenty-four-hour deposit. The neutral dyes used, however, are such as have no influence on the clay and on its action.

A Rust-Proofing Process.

A new rust-proofing process has been introduced abroad, for which great efficiency is claimed. The articles to be treated are first cleaned with emery paper, or by sand blasting, and then placed in a wire basket which is inserted into an airtight muffle that has been previously heated. Superheated steam is then turned into the muffle for 30 minutes to prepare the surfaces for the subsequent treatment. The steam is then shut off, and the chemical powder used for coating is placed in a rear extension of the muffle, which is heated by gas jets. This vaporizes the chemical, and the fumes are forced into the main muffle under pressure, giving the articles their protective coating. On removal from the muffle the pieces, which have a light gray color, are covered in order to cool slowly. If desired, the articles can be dipped in oil while still hot, which gives them a rich blue-black color; or they may be painted, as paint adheres strongly to the coated surface. The chemical used for coating is not disclosed, but is said to be non-poisonous and non-explosive.

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The Chemistry of Amorphous Solids*

Some Generalizations Based on Recent Researches

By Warren H. Lewis, Ph. D.

DURING recent years a great deal of research has been carried on in the field of colloidal chemistry and the closely allied chemistry of amorphous bodies and plastics. A great mass of data and results has been accumulated, but this mass of facts is still largely unrelated, and the generalizations which would serve as a filing system for these facts have not been developed. It is proposed to submit certain generalizations in this field which it is believed are justified by the results of recent work. These propositions are not presented as ultimate in any sense because, in the first place, our knowledge is still too imperfect to justify such finality, and, in the second place, such finality is always disastrous to the progress of science. It is hoped that these generalizations will prove helpful, and will promote a discussion which will tend to perfect them and to lead to a deeper knowledge of the truth. In this attitude, certain theses are proposed as defendable general propositions.

IMPORTANCE OF AMORPHOUS SOLIDS.

Some solids possessing desirable mechanical properties, especially high tensile strength, high elastic limit, ductility, and plasticity, owe these properties to their amorphous condition.

Plasticity may be defined as that property of certain solids which enables them to be molded, i. e., to sustain permanent deformation after stress without rupture, and which causes free surfaces brought together to coalesce under pressure. Not only the properties of solids ordinarily connected with the word, but the capacity of metals to be wrought, spun, and welded below the melting point are due to their possession of plasticity.

It must not be assumed that all amorphous solids have desirable mechanical properties, for this is not the case.

THESES.

1. All, or nearly all, amorphous solids are composed of large molecular aggregates.

2. The molecular aggregates of most amorphous solids can be conceived as built up of a relatively small unit, V (or units V′, V″, etc.) grouped together or associated by polymerization, condensation, or otherwise, a large number of times, n, the result being represented as V_n (or V'_n, V''_n, etc.). Illustrations: Cellulose, $(C_6H_{10}O_5)_n$. Rubber, $(C_5H_8)_n$. Gelatin, condensation product of several amino acids.

3. Usually, in an amorphous solid, V_n, the value of n is not fixed, but the solid consists of molecular aggregates of varying size, due to a varying degree of association of the unit, V. i. e., to varying values of n. No assumption is made regarding the mechanism of association of the units; it is probably chemical combination. While, from the nature of the assumption, n is necessarily an integer, it is probably in most cases not true that n can assume any integral value, but the various possible values of n will differ by relatively large whole numbers. This is due to the fact that in all probability the unit, V, first associates into small groups, further association being due to combination of these sub-groups (e. g., starch, cellulose, etc.)

4. The characteristic properties of all amorphous solids are first, plasticity, and second, relative inertness, chemical and physical.

Plasticity is decreased, and chemical and physical inertness is increased (*a*) by any increase in the size of the molecular aggregate, V_n, and (*b*) by drop in temperature; and conversely, the swelling of amorphous solids in solvents is due to the distention of an insoluble and semi-permeable residue by the osmotic pressure of a dissolved portion.

The following explanation will make this statement clearer. If a solid composed of aggregates of varying size be treated with a solvent under such conditions that the larger aggregates do not dissolve, but the smaller do, the undissolved part serves as a semi-permeable membrane, through which the solvent can freely diffuse, but which is impermeable for the dissolved material, enclosing the solution of the soluble fraction. The osmotic pressure of this latter distends the mass, producing the swelling of amorphous solids in solvents. Ultimately this osmotic pressure may rupture the retaining wall, thereby disintegrating the aggregates, decreasing the average value of n in N_n, and thus render the whole "soluble." In general even the "soluble" fraction has a high molecular weight, and hence only a low osmotic pressure. Illustrations: gelatin in water; rubber in carbon bisulphide, etc.

It is not intended to deny the possibility of combination of a solvent with even the largest of the molecular aggregates involved, nor to assert that the solutions formed are not colloidal in character. It is probable that the molecular aggregates, both large and small, of all jellying or gel-forming amorphous solids combine with the solvent, probably by an association chemical in its nature.

In consequence of the influence of the size of aggregates upon plasticity and inertness, it is evident that solvents tend to increase plasticity, and to decrease chemical and physical resistivity.

5. Excessive mechanical manipulation of amorphous solids ruptures the molecular aggregates themselves, and consequently results in decrease in the size of the aggregates, producing increase in plasticity and decrease in inertness. Illustrations: manipulation of rubber; working of metals.

6. The utility of amorphous solids is due largely to their property of plasticity, i. e., by virtue of their plasticity they can be formed at will. After molding it is usually necessary to decrease plasticity to secure permanence of shape, hardness, and resistivity. This decrease in plasticity is always secured either by lowering temperature, or by increase in the size of the molecular aggregate.

METHODS OF MANIPULATION OF PLASTICS.

The methods of manipulation of plastics can be grouped under seven heads; and such a grouping will be found helpful in keeping in mind the possibilities of manipulation in any given case, in comparing the treatment of different substances, and in emphasizing the analogies between different types of plastics.

1. The required distortion is produced by mechanical stress; rigidity of the mass is such that further treatment is unnecessary. Illustrations: rolling, spinning, and working of the metals; cold-pressing of organic plastics, etc.

The behavior of the metals cannot be explained on the basis of their plastic properties alone, for the simple reason that the metals do not consist solely of plastic or amorphous material. Rosenhain has shown that the amorphous material in the metals is merely a small amount of bonding substance between crystal grains, and the characteristics of the metal will therefore be dependent both upon the properties of the grains and of the amorphous bond between them. For example, in the cold working of the metals, i. e., in distorting them beyond their elastic limit but not to the point of rupture, there is unquestionably destruction of the crystal structure, resulting first in decrease of the size of the crystals, second in partial conversion of the crystalline condition into the amorphous state, thus increasing the amount of bond between the crystal grains, and finally, in some cases at least, in the formation of new crystalline structure. There is also undoubtedly a certain amount of mechanical disintegration of the amorphous material already existing, which will result in increased plasticity of that material. On the other hand, the total amount of amorphous material is still a small fraction of the whole mass. While the increase in plasticity will tend to result in increased ductility and softness, the decrease in strength of the amorphous bond will tend to cause readier rupture of the mass as a whole, and in some cases the one and in some the other of these factors may predominate. For example, in the rolling of zinc the increase in bonding material is apparently a more important factor than the decrease in strength of that material, and as a result rolled zinc is softer and more ductile than unrolled. On the other hand, in the case of copper the rigidity of the new crystal aggregate produced is the more important factor, so that, despite an increase in plasticity of the bond, the mass as a whole is harder rather than softer. In any application of the general properties of amorphous material to a study of the behavior of metals under stress, the fact that the metal consists of a mass of crystal grains cemented together by only a small amount of amorphous bond must be kept constantly in mind, and the possibility of conflicting effects makes the problem a much more difficult one than that of a material amorphous throughout.

2. Plasticity is secured by rise in temperature; rigidity is restored by cooling. Illustrations: glass, bitumens, celluloid, and hot-pressing of organic plastics; hot working of metals.

The cause of the increase of plasticity of all amorphous bodies with rise in temperature is the decrease in their viscosity. The assumption that such bodies are supercooled liquids, xisting at temperatures so low that the viscosity is very great, seems the best interpretation of the facts. That the increase in plasticity may be due to dissociation of the molecular aggregates into smaller groups at higher temperatures seems very unlikely in those cases where the phenomena are practically reversible, unless decrease in viscosity itself be due to this effect; in cases such as the heating of rubber, where irreversible changes occur, disintegration of the aggregates undoubtedly takes place.

Only those plastics having very high softening points will be thoroughly rigid and stable at ordinary temperatures, because only at temperatures far below the softening point will the viscosity become sufficiently great. The really stable and therefore valuable organic plastics can, in consequence, not be manipulated by raising the temperature, since the required rise would be so great that decomposition would follow. The stable and important glasses are necessarily inorganic in structure.

3. The action of a solvent secures plasticity; its removal destroys plasticity. Illustrations: celluloid, artificial silk, sun-dried brick, etc.

4. After manipulation of a plastic, plasticity is destroyed by chemical conversion into a new and less plastic body.[1] Illustrations: ceramics, cement, plaster.

5. Plasticity is lessened by increase in the size of the molecular aggregate, produced by co-precipitation of two amorphous materials existing as colloidal solutions or gels of opposite sign.[2] Illustration: co-precipitation of hide substances and tannins as leather.

The leather industry furnishes many striking illustrations of the generalizations indicated above. Hides are usually treated as follows: first the rehydration of the skin if previously dried, almost always assisted by alkali; second, the removal of the hair, generally by the action of alkalis or alkali sulphides; and third, the precipitation of the hide substance by the action of colloidal solutions of so-called tanning agents, which act, however, only in an acid medium. Hide substance is a condensation product of a number of amino acids, the degree of association of these acids being unquestionably very great. On the other hand, it is undoubtedly true that certain of the aggregates are much larger than others. It is probable that the cell wall is the more highly aggregated constituent, and that the contents of the cell, while in general similar in character, i. e., consisting of condensation products of amino acids, are much smaller in size. Both components are capable of combination with water, i. e., of hydration. The cell will form, however, only a gel, while the cell contents form a solution, colloidal in character on account of the large size of the molecular aggregates composing them. In its natural state hide substance is already hydrated. Upon drying, the moisture evaporates, plasticity decreases, and the hard and horny effect of dried hide is produced. The hide is capable of rehydration upon treatment with water, and the osmotic pressure of the solution of the cell contents serves to distend the mass and to produce the swelling observed upon soaking hides and skins. The cell contents, composed as they are of condensation products of amino acids, possess both free amino and carboxyl groups, and can, therefore, function either as an acid or a base, i. e., are amphoteric in nature, the basic character being somewhat stronger. If treated with either an acid or a base of which the molecular weight is sufficiently small that diffusion through the cell wall is possible, a salt is formed; the amphoteric electrolyte within the cell is so weak that its dissociation is negligible, while on the other hand, the salt formed is largely dissociated, as is true of all salts of this type; but nevertheless the ion formed from the cell contents—whether positive or negative, depending upon the use of acid or base—is too large to be able to diffuse through the cell wall. It, therefore, holds by electrostatic attraction its corresponding ion from the acid or base within the cell, thus doubling the molecular concentration in the cell, and also doubling the osmotic pressure. This increase in osmotic pressure increases both the rate and the extent of the distention of the skin, pulling the water necessary for the expansion of the cell contents through the cell walls themselves, and thereby greatly increases the rate of their hydration. For the rehydration of dried hides and skins dilute alkali is used to produce this effect, because its action is less violent than that of dilute acids and its use is therefore safer. On the other hand, co-precipitation of the tanning agents with the skin is impossible in alkaline solutions, and tannage must, therefore, take place in an acid medium. For the production of thick leather it is thus necessary to

* A paper read before the New York Section of the Society of Chemical Industry, and published in its *Journal*.

[1] Mellor holds that under the action of heat kaolin decomposes to form free alumina and silica, the water escaping; owing to the inertness of these bodies, recombination to form the original kaolin does not take place.

[2] The separate particles of all colloidal solutions and gels carry electrostatic charges either positive or negative in sign, depending both on the particular substances involved and on the conditions of formation and existence.

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secure the preliminary swelling of the hide by the use of dilute acids, the action being, however, entirely analogous to the welling in alkalis.

The agglomerates of amino-acids which compose the hide substance are easily capable of hydrolytic disintegration into smaller aggregates more plastic but also more soluble and mechanically weaker and unsatisfactory. This hydrolysis is promoted by certain ferments, and especially by hydrogen ions.[3] On this account the use of acid for swelling is dangerous and is sure to result in weakening of the hide to a greater or less extent. The function of tannage is first to render the hide inert to this process of hydrolysis, and second, to destroy its affinity for water so that osmotic swelling and disintegration will not occur. In order to do this the physical and chemical inertness of the materials is increased by increasing the size of the aggregate through co-precipitation of the hide substance with some sort o tanning agent, the solution of some colloid of opposite sign, such as the tannins, metallic hydroxides, aldehydic condensation products, etc. The increased resistance to the action of chemicals and solvents is characteristic not only of this particular process, but, as has been pointed out, is a general accompaniment of any increase in the size of the molecular aggregate.

Many of the phenomena of leather chemistry become clearer in the light of the generalizations which have been given. A single one must suffice at this point. It is a well-known fact that chrome leather upon drying loses its affinity for dyes. The probable explanation of this would seem to be that the first product of the tannage of leather by basic chromium sulphate is a co-precipitation of hydrated basic sulphate and hide substance. Upon drying, this precipitate loses its water of hydration, and is converted into a co-precipitate of hydrated basic chromium sulphate and hide substance which is incapable of rehydration. This change is similar in character to the transformation taking place in the burning of ceramics, i. e., the dehydrat on of kaolin and its transformation into a new amorphous body incapable of reversion.

6. In the complex, V_n, the size of the molecular aggregate is increased by increasing n. Illustrations: Bakelite, and all other condensation products.

[3] It is possible that the disintegration by acids is entirely due to osmotic swelling.

7. In the complex, V_n, the size of the molecular aggregate is increased by increasing V. Illustrations: rubber, linoxylin, rubber substitutes (sulphurized oils), oxycellulose. In this case, a small change in the unit, V, produces a great change in plasticity and resistivity.

Rubber chemistry is one of the most fascinating fields for the application of the new ideas regarding colloids and amorphous bodies. Apparently isoprene is capable of polymerization only to a limited extent. In other words, in the formula $(C_5H_8)_n$, n has a maximum value beyond which it cannot or does not go. This value of n is not sufficient to reduce plasticity to the necessary degree. The reason for assuming this is the fact that by no method of polymerization alone have we yet been able to decrease the plasticity of ordinary rubber; in other words, it is assumed that in or inary rubber the polymerization has gone about as far as it is possible to carry it. On the other hand, it is always possible to decrease the value of n in the rubber complex. This can be done either by the action of heat or by the action of solvents, in which case the smaller rubber aggregates unquestionably dissolve and, by their osmotic pressure against the retaining walls of the insoluble port on of the rubber, disrupt that portion and disintegrate it into smaller groups or by mechanical manipulation. It is, however, possible to increase the size of the rubber aggregate by the introduction of sulphur into the isoprene unit, probably by direct addition at one of the double bonds. It has been suggested that the vulcanizing action of sulphur is due primarily not to this introduction of sulphur into the rubber molecule, but to an accompan ing catalytic action upon the polymerization of rubber. This seems unlikely for two reasons: first, because it is difficult to explain our inability to find any other catalytic agent for this polymerization except such as also combines chemically, and in the second place, because the known cases of chemical combination with the unit of an organic complex also produce, as in this case, marked changes in physical properties, very great in proportion to the amount of chemical action involved. One will recall the enormous increase in inertness of linseed oil corresponding to a relatively small addition of oxygen, the great decrease in strength and resistivity of cellulose upon the formation of oxycellulose, and the changes accompanying the addition of sulphur to oils in the production of rubber substitutes. It therefore seems more reasonable to assume at present that an increase in the size of the unit, V, of an aggregate is more important than a corresponding change in n.

By the introduction of a small amount of sulphur into the unit, V, of the aggregate, V_n, it is possible very greatly to decrease plasticity and to increase resistivity; and furthermore the extent of these changes can be controlled by the amount of sulphur combined. The product may be represented as $(VS_x)_n$, wherein x is small in comparison with the total amount of sulphur which the polyprene is capable of absorbing. If, however, the rubber has before vulcanization been partially disintegrated, by heat, solvents, or manipulation, its formula is V_n', where n' is less than n. It is still possible to decrease plasticity and increase inertness to any desired degree by the introduction of sulphur, but to carry these changes to the same extent, a larger amount of sulphur must be combined, giving a product, $(VS_x')_n'$, where x' is greater than x. While plasticity and resistivity may now be the same as before, the product is evidently a different one, and it is not surprising to find that rubber so treated has mechanical properties differing—less satisfactory.

Again, it is possible to disintegrate the vulcanized aggregate, $(VS_x)_n$, by the action of solvents and heat, and, as is to be expected, it is possible to restore plasticity thereby. The product is devulcanized rubber, using the term to indicate only material to which plasticity has to a greater or less degree been restored. Since the capacity of the unit for the addition of sulphur has not been exhausted, it is possible once more to destroy plasticity by vulcanization, but as in the previous case the product is by no means identical with the result of the vulcanization of the original rubber, and it is, therefore, not surprising that such revulcanized rubber is mechanically different—again inferior—to the original article.

In conclusion, a few words regarding the relation between amorphous bodies and colloids are necessary. Apparently the removal of the solvent from any colloidal solution or gel leaves an amorphous body behind, but it does not follow that all amorphous bodies can be brought into colloidal solution, although this is frequently the case. While the relations between the two states of matter are not entirely clear, it is believed that any uncertainty in this respect will not affect the generalizations that have been made regarding amorphous solids.

Invar and Related Nickel Steels

Materials Having Peculiar Properties of Value for Scientific Instruments

Much interest has been disclosed in relation to Invar, that nickel-steel alloy whose peculiar properties make it of special value in the construction of scientific instruments, as well as in a constantly increasing number of commercial applications; and for this reason the pamphlet recently issued by the Bureau of Standards, Circular No. 58, will be widely appreciated. The following extracts, giving a few historical and general facts in regard to the alloy, are derived from that source.

Ferronickels were first made commercially in France in 1885, and our knowledge of them goes back to a publication by Stodart and Faraday in 1822.

In 1889 James Riley, of Glasgow, described before the Iron and Steel Institute his epoch-making investigation which disclosed the remarkable mechanical properties of nickel steels. His tests were made on a series of alloys containing various amounts of nickel up to 49 per cent, which had been prepared for him in France by the inventor, Marbeau. At the conclusion of Riley's lecture J. F. Hall, of Sheffield, announced that he, too, had for some time been experimenting with nickel steels; and he supplemented Riley's statements by describing the superior qualities which these steels had exhibited when made into various articles that were subjected to severe treatment.

Later in the same year Hopkinson discovered that a sample of 25 per cent nickel steel furnished to him by Riley was practically nonmagnetizable at ordinary temperatures, the permeability being only about 1.4 and the induction proportional to the magnetizing force. It retained its nonmagnetic condition while being heated up to 700 deg. or 800 deg. Cent., and it did not recalesce on cooling from a high temperature. But when the temperature was reduced to a little below 0 deg. Cent., ferromagnetic properties appeared, which were strongly intensified by further cooling. Moreover, cooling to below — 50 deg. Cent. with solid carbon dioxide effected such a transformation that, when the specimen was returned to 13 deg. Cent., it was found changed from a nonmagnetizable to a decidedly magnetizable substance; and it remained magnetizable on heating until 580 deg. Cent. was reached. In the neighborhood of this temperature it again became nonmagnetizable and continued so on cooling to the temperature of the room. By these experiments Hopkinson showed that the material can, at ordinary temperatures, exist in either of two quite different states, both of which are stable. In passing he pointed out that the same kind of thing can be seen in a much less degree at a higher temperature with ordinary steel.

Early in the following year (1890) Hopkinson described the results of further experiments on wire of the same material. Among other things he showed that the heat treatment which caused such remarkable changes in permeability produced corresponding changes in the electrical resistance and in the elastic properties. For example, changing from the nonmagnetizable to the magnetizable condition changed the electrical resistivity at room temperature from 72 to 52 microhm-cm[1] and the ultimate tensile strength from 50 tons weight per square inch with 32 per cent elongation to 87 tons weight per square inch with 7.5 per cent elongation. A few months later Hopkinson brought out still another paper, in which he described the magnetic properties of a graded series of steels containing from 1 to 73 per cent nickel; and in June of the following year (1891) he pointed out that the transformations of the 22 per cent and the 25 per cent alloys from the nonmagnetizable to the magnetizable state by cooling to — 100 deg. Cent. were accompanied by such increases in volume that the densities on return to room temperature were found lowered by about 2 per cent.

Systematic studies of the methods of manufacture of nickel steels and nickel-chrome steel, suitable for military purposes—armor plate, cannon, etc.—were carried out on an extensive scale by the metallurgical plants of Europe and America during the decade 1890 to 1900. The metallurgists and engineers associated with certain works, notably those of Hadfield in Sheffield and the French firms of Saint-Etienne and Commentry-Fourchambault d'Imphy, made a series of elaborate investigations of the properties of nickel steels, including many combinations of nickel with iron; the effects of carbon, manganese, and other elements; and the changes due to heat treatments. These studies are set forth at length in the papers of A. Abraham (*Annales des Mines*, 1898), and particularly in that of A. Dumas (*Annales des Mines*, 1902), metallurgist of the Société de Commentry-Fourchambault, who has made the most thorough and complete metallurgical contribution to our knowledge of nickel steels. These investigations showed that the pure ferronickels—i. e., those containing little or no carbon—were of very different properties from the nickel steels. Dumas also showed that it was not practicable to manufacture without adding manganese, which element, in proportions 0.30 to 0.70 per cent, appears necessary to obtain a forgeable material, which may be made in either the open-hearth or the crucible furnace. Dumas notes that, in general, nickel gives a fibrous texture to steel, increases its tenacity, ductility, and resistance to shock and to oxidation, and to a less degree improves its hardness.

Osmond, in a series of contemporaneous investigations on the interrelations between the composition, thermal treatment, metallography, and physical properties, was able to give the first clear rational explanation of the latter in terms of the transformations in the nickel steels. This has permitted a ready classification of the nickel steels, which will be mentioned later.

During 1895 Benoît, then director of the International Bureau of Weights and Measures, in the course of calibrating a length standard of steel containing some 22 per cent nickel and 3 per cent chromium, discovered that the linear coefficient of thermal expansion at ordinary temperatures was more than 18×10^{-6} per degree Centigrade, or about as great as that of average bronze—that is to say, considerably greater than that of either iron or nickel. Somewhat over a year later Guillaume found the expansion of a bar of 30 per cent nickel steel to be about one third less than that of platinum, which has a coefficient of only 9×10^{-6}. In the hope of obtaining alloys of very small expansivity by increasing the proportion of nickel, Guillaume, with the co-operation of the Société de Commentry-Fourchambault, carried out an elaborate study of nickel steels of varied composi-

[1] A resistivity of 1 microhm-cm means that a rod having a cross-sectional area of 1 cm² will have a resistance of 1 microhm per centimeter of its length. The designation "microhm-cm" is now replacing the familiar "microhms per cm³."

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tion. This resulted in the discovery of alloys having coefficients of linear expansion at ordinary temperatures ranging from a small negative value (about -0.5×10^{-6}) to a rather large positive value (about 20×10^{-6}). The dimensions of the alloy containing about 36 per cent nickel along with small amounts of manganese, silicon, and chromium, in all about 1 per cent, were found to remain almost invariable with ordinary atmospheric changes of temperature. For this reason, Guillaume, at the suggestion of Prof. Thury, named it "Invar." The alloy containing 46 per cent nickel and 0.15 per cent carbon, which was found to have nearly the same expansivity as the glass of incandescent electric-light bulbs, and has consequently been used to replace platinum for the sealed-in wires, was called "Platinite."

As Hopkinson had previously found from measurements of magnetic induction, so Guillaume found from measurements of thermal expansion that nickel steels do not follow the usual law of mixtures, but present marked anomalies.

These discoveries of Riley, Hopkinson, Dumas, Osmond, and Guillaume formed the starting point of many important investigations which have resulted not only in accumulating much data on the properties of nickel steels, but also in developing theories for explaining their peculiarities.

SUMMARY OF PROPERTIES OF INVAR.

Invar is a nickel-steel containing about 36 per cent nickel together with about 0.5 per cent each of carbon and manganese, with metallurgically negligible quantities of sulphur, phosphorus, and other elements. It is made either in the open-hearth furnace or by the crucible method. It melts sharply at about 1,425 deg. Cent. Above some 200 deg. Cent. to its melting point, invar may be considered to consist of a homogeneous solid solution of iron, nickel, and carbon. Below 200 deg. Cent. and at a temperature dependent on its history and exact composition it undergoes a reversible transformation of such a nature that for any sample the transformation may be incomplete. This condition of thermochemical instability gives rise to both slowly changing and quickly changing values of its physical properties—changes which are particularly manifested in the expansion.

The alloy invar can be forged, rolled, turned, filed, and drawn into wires; and it takes a beautiful polish, giving an excellent surface on which fine lines may be ruled. In general, it should be worked slowly. It will withstand without spotting the corrosive action of water, even when immersed for several days. Its density is about 8.0 grammes per centimeter^3; its electrical resistivity is of the order of 80 microhm /centimeter, or about 8 times that of pure iron; and its temperature coefficient of electrical resistance about 0.0012 per degree Centigrade. It is ferromagnetic, but becomes paramagnetic in the neighborhood of 165 deg. Cent.

The mean coefficient of linear expansion between 0 and 40 deg. Cent. is of the order of one millionth for the ordinary invar, and samples have been prepared with even small negative coefficients; the amounts of carbon and manganese present appear to exercise considerable influence on the expansion. Small quantities have been manufactured with a coefficient $(+0.028 - 0.00232\ t)\ 10^{-6}$, equivalent to a change in length of 0.4 millimeter in 1 kilometer between 0 and 20 deg. Cent. This was for one alloy containing 0.06 per cent carbon and 0.39 per cent manganese, the other elements being negligible. Above 200 deg. Cent. the expansion of invar is nearly that of Bessemer steel.

Invar is subject to changes in length due to "after effects" following cooling from a high temperature, and to changes in length following even slight alterations in temperature. For example, at 15 deg. Cent. the elongation of 1 meter is 0.07 to 0.08 μ per day after forging and 0.03 μ after annealing to 40 deg. Cent. After a long rest at room temperatures (10 to 20 deg. Cent.) the contraction setting in after bringing the metal to a higher temperature is completed in about one half hour at 100 deg. Cent. and only after several days at 40 deg. Cent. The range of transitory length variations following temperature changes is given approximately by the formula:

$$\triangle L/L = -0.00325 \,.\, 10^{-6} t^2$$

which holds for temperatures between 0 deg. and 100 deg. Cent.

Invar also gradually elongates with time, forged and drawn material behaving somewhat differently in this respect, so that there is a determinable, seasonal correction to be applied to its length when used as a length standard. This effect may be reduced, but not entirely eliminated, by special heat treatments consisting in an annealing process extending over several weeks carried out at successively decreasing temperatures.

Invar also shows marked magnetostriction phenomena, or changes of length accompanying changes in strong magnetic fields.

The invar from a single melt will not, in general, be of absolutely uniform properties throughout, the expansion variations not being more than $\pm 0.03 . 10^{-6}$, so that, in determining lengths to one part in ten million, it appears safe to use the same expansion formula for all the pieces from a given melt.

The mechanical properties are about as follows: Tensile strength 35 to 60 kilogrammes per square millimeter, or 50,000 to 85,000 pounds per square inch; elastic limit 5 to 21 kilogrammes per square millimeter, or 7,000 to 30,000 pounds per square inch; elongation 40 to 50 per cent; reduction of area 40 to 65 per cent; scleroscope hardness 19; and Brinell hardness 160.

APPLICATIONS.

The applications of nickel steels depend naturally upon their properties, or to the group to which they belong; and the properties of each group suggest possible applications of those steels within that group. The steels of the first group, usually containing less than 5 per cent nickel, have a high elastic limit and high tensile strength. They are used for armor plate, guns, large axles, automobile parts, and structural purposes. Steels with a larger nickel content are very hard, take a good polish, resist oxidation, and have a higher elastic limit and tensile strength than carbon steels of the same hardness; so they may replace carbon steels where hardness is the property desired.

Further increase of nickel lowers the elastic limit and tensile strength, but greatly increases the elongation. Nickel steels of this third group are very resistant to shock, and may be used in machine parts which are designed to receive violent shocks. Steels of this group cover a wide range of expansion coefficients and anomalous variations of the elastic modulus. They are used in the manufacture of clocks, watches, and scientific instruments; and also for measures of length, measuring tapes, etc.

Invar is being used extensively for length measures. It has proved to be an excellent material for tapes. The United States Coast and Geödetic Survey has found invar tapes far superior to steel tapes, it being possible to measure a base line more rapidly and with greater accuracy than with steel tapes. The advantage arises mainly from the low expansion of invar, measurements being made in daylight with very small corrections for temperature. This bureau has found that invar tapes which have been properly manufactured vary less than one part in 500,000 after six months' use in the field. There have been cases where invar tapes changed length between calibrations, but in practically every instance the cause could be traced to lack of proper treatment during the production or use of the tape.

French investigators have constructed length measures of invar in the form of wires instead of tapes. Tapes are more trouble to handle in a breeze, but wires twist and introduce errors in measurements which are not evident. The United States Coast and Geodetic Survey have found that wind caused little delay in the use of tapes, while the errors due to twist in wires were appreciable.

The low expansion of invar has been used to advantage in the construction of instruments requiring fixed distances between points to be independent of temperature, such as the bar between microscopes of a comparator for length standards. Nickel steels with low expansion have also been used for boiler tubes.

Industrial measuring machines constructed of 56 per cent nickel steel avoid temperature corrections in testing the dimensions of steel gages and machine parts, since this alloy has about the same thermal expansivity as ordinary steel. In addition, it is more stable and less subject to corrosion.

Platinite, a nickel steel with about 46 per cent nickel, has the same expansion as platinum and has taken the place of platinum for sealing-in leads in electric-light bulbs. Nickel steel with the same expansion as glass, is also used in mounting lenses of optical instruments, diminishing the possibility of strain in the glass.

The application of invar and related nickel steels to the construction of clocks and watches has resulted in a great increase in the accuracy of instruments for measuring time. Invar, or a nickel steel with a low expansion coefficient, has made possible the compensated clock pendulum without mercury, resulting in convenient design and greater accuracy.

The use of nickel steel with a low coefficient of expansion in balance wheels of chronometers has made possible good compensation over a fairly wide range of temperature instead of for two definite temperatures.

The very convenient quality of abnormal variation of elastic modulus with temperature has been utilized in the manufacture of watches by making the hair spring of a nickel steel with the addition of a little chromium to raise the elastic limit. A fair degree of compensation is obtained quite cheaply in this manner.

Clocks with tŏrsion pendulums require little driving power and are constructed to run 400 days on a single winding. Compensation is obtained by making the torsion pendulum of nickel steel.

The high electrical resistance of 25 per cent nickel steel has also been of commercial importance. The steel called ferronickel is employed in the construction of rheostats.

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Patent Solicitors,
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