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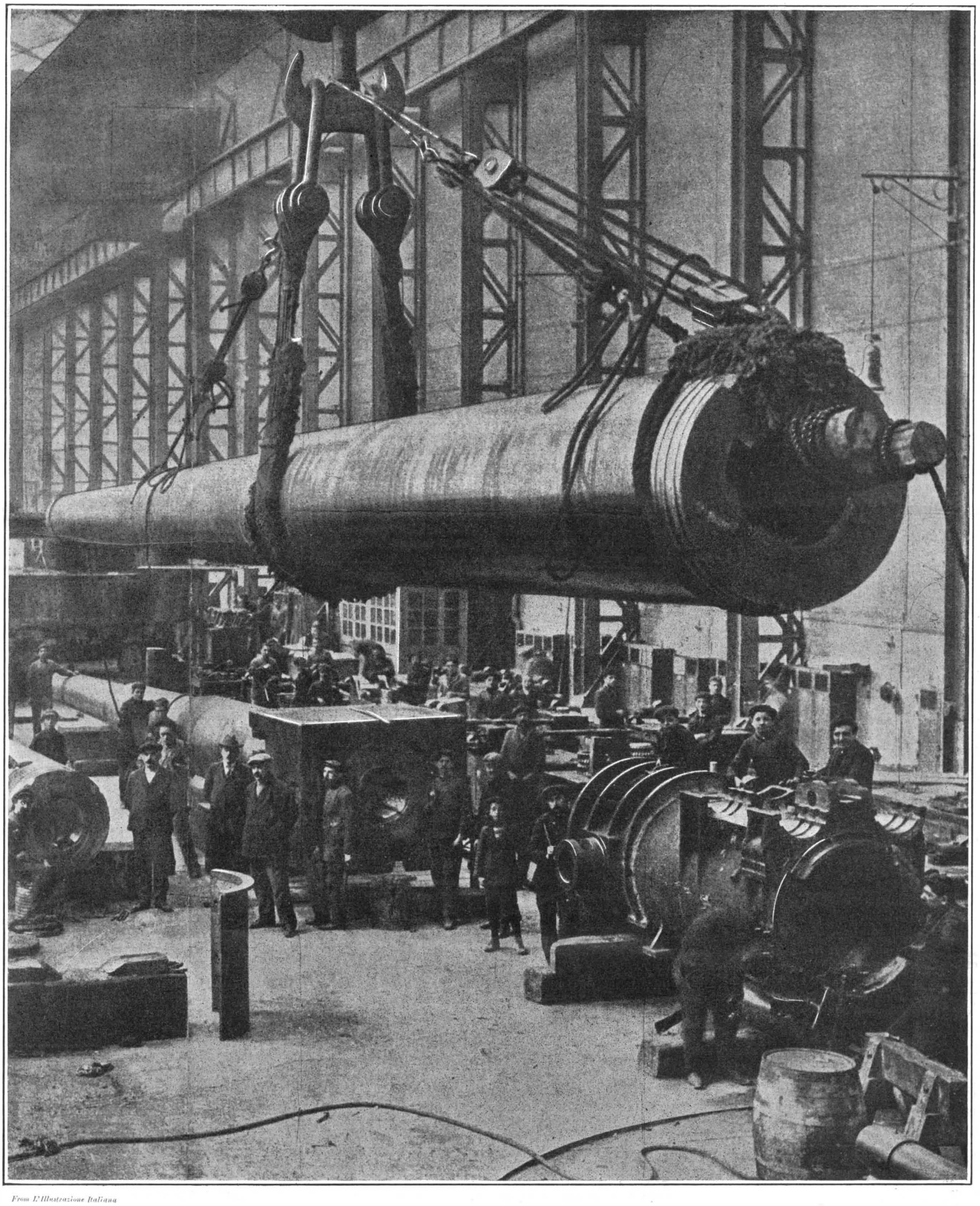


From L'Illustrazione Italiana

Building 15 inch, 40 caliber guns in Italy.

THE BIG GUNS IN THE WAR.—[See page 184.]

The Metabolism of Insects—I*

Successive Changes Undergone During Their Post-Embryonic Lives

By August Lameere, Professor in the University of Brussels

I.

In the discussion of many biologic problems the attention is from the start distracted by minute and trying considerations of phraseology, arising from the use either of the same expression to designate different phenomena, or of certain terms in other than their generally accepted connotations. It is in this way that we are obliged to employ the word *metabolism* to designate the successive changes undergone by insects during their post-embryonic lives; for these are of so diverse a nature that their general inclusion under the caption *metamorphosis* would lead to grievous confusion.

Giard has clearly defined what should be understood by metamorphosis. The majority of zoologists are to-day in accord with his view that, in contrast with a continuous and regular process of evolution, metamorphosis is discontinuous and in some respect revolutionary, that in somewhat technical language it is a normal necrobiosis effected by amputation, by degeneration, or by phagocytosis. The elimination of the amnion and the placenta among the monodelphian mammals, the absorption of the tail of the tadpole, the transformation of the caterpillar into the butterfly—all these are phenomena of metamorphosis.

It is necessary to guard against confusion of metamorphosis with what, borrowing an expression from the distinguished English entomologist Westwood, we may call *heteromorphosis*. The latter is distinguished by a very special type of difference between the first state of post-embryonic development and the permanent form—the acquisition on the part of the young animal of new features which are distinctly larval characteristics, which did not exist among its ancestors, which will disappear upon the attainment of adulthood, and which constitute merely a provisional adaptation of the organism to an environment different from that which it will have in its permanent state. The young is then a larva. The horny beak and the long intestine of the tadpole, the trachean gills exhibited by the ephemerids—the May flies or day flies—during the aquatic stage of their life, are heteromorphic characteristics.

Heteromorphosis may exist without subsequent metamorphosis, the transformation of the larva into the adult insect then being a gradual process. It is this that we see in general among the crustaceans. Equally, metamorphosis may manifest itself without previous heteromorphosis; the tail of the tadpole is an hereditary organ, and not a larval adaptation. Among the higher insects, however, heteromorphosis is pronounced and is invariably followed by a profound metamorphosis.

We see then that we must avoid associating with the idea either of metamorphosis or of heteromorphosis the casting of the outer covering so general among insects of all grades. This phenomenon is a simple external manifestation of growth on the part of the animal. Nevertheless, among the winged insects, the manner of appearance and growth of the wings by successive and discontinuous increments coincident with the successive castings gives a very particular aspect to the evolution of these organisms, and constitutes a third sort of change of which we must take account in a complete exposition of post-embryonic transformations.

Contrary to the procedure of Heymons, we shall employ the term "metabolism" in the most general sense, without identifying it with "heteromorphosis." It may be that the word is indeed thus diverted from its original significance. But the more competent authorities have always used it to designate the entire group of rapid transformations to which the winged insects are subject. So we shall do likewise and, with Henneguy, shall speak of *ametabolism*, *paurometabolism*, *hemimetabolism* and *holometabolism.*

II.

For the past decade we have been acquainted with certain very singular hexapods, the *Protura* or *Myrientomes*, found first in Italy, later in Germany, Austria, Russia, the East Indies, Java and North America. They are extremely small and difficult to locate in the damp earth into which they burrow to considerable depths. The extent to which this remark is true is shown by the fact that while several species should by all indications exist in France, they have not yet been seen there. These animals, destitute of eyes and antennae, and having three pairs of degenerate legs upon the abdomen, have been variously looked upon as true myriapods, as marking the transition between these and the true insects, or as belonging to the *Apterygota*, a group of very primitive wingless insects. It at length appears that we have to do here with true insects, extremely specialized, set apart from all other insects by a peculiarity which makes their development quite unique, and which has perhaps some connection with the phenomenon of anamorphosis found in many crustaceans and myriapods. On emerging from the egg the *Protura* show only nine abdominal segments, three more being, in the course of time, interposed before the hindmost one so as to bring the total up to twelve. All the other hexapods, which are *epimorphic*, possess from birth the complete number of abdominal segments, uniformly twelve.

The epimorphic Apterygota—the *Thysanura*, the *Campodeae* and the collemboles—present neither heteromorphosis nor metamorphosis. It is true that upon leaving the egg they often differ from their parents in color and in certain temporary imperfections of their appendages, as well as in the shape and rudimentary state of the genital organs. But in this respect they are not to be set apart from the young of a multitude of other animals, the spiders for instance; and as their race has never had wings, their castings present no distinctive features and we may consequently consider them to be purely *ametabolic.*

III.

The lower pterygots—that is to say, the *Paleodictyoptera* of the Carboniferous formations, ancestors of all the other winged insects, the *Orthoptera* (using the word in its largest sense), and the *Hemiptera*—are frequently referred to as insects of incomplete metamorphosis. In reality they present no metamorphosis at all, nor even heteromorphosis. The young differ from the adults in the same way as among the ametabolians, but the gradual development of wings, marked externally by discontinuities coincident with the castings, constitutes, as already noted, a distinct type of evolution. This is *paurometabolism.*

Again, the young grasshopper, while in a highly precarious state of development at birth, still resembles his parents, except that he has no wings. These manifest themselves at each change of skin, in manner more and more accentuated, until they have attained the final state of functional perfection. There is here nothing foreign to what is seen among the birds or even the mammals, where organs peculiar to the adult develop during adolescence. The freshly hatched grasshopper is no more a larva than is the freshly hatched chicken, for it presents absolutely nothing in the way of special or provisional adaptation. Above all it is in no way comparable with the larvae of the holometabolic insects to be considered below, as was shown long ago and as can be demonstrated at any time. Berlese has suggested the name *prosopon* to designate this particular type of infant.

Up to a certain point the semi-winged form which precedes the final casting may be identified with the pupa of the holometabolians. This merely necessitates that we divorce from our notions of the pupa those phenomena of inactivity, and especially of metamorphosis, which are associated with the presence of external wings in the pupae of the higher insects, and which are lacking among the paurometabolic forms.

If the passage from pupa to adult among the latter is always effected without revolutionary change, we nevertheless recognize cases in which it is accompanied by a period of repose comparable with that of a chrysalis. It is this that we see in the *Thripsidae* or *Thysanoptera*. But we have to do here only with an exaggerated instance of a general peculiarity which we may identify as precisely the origin of the period of pupal inactivity in the holometabolians. Each casting by an arthropod is in fact a moment of crisis strongly coincident with a more or less prolonged arrest of organic activity.

Among the *Orthoptera* and the *Hemiptera* we encounter a goodly number of forms having lost their wings. The louse, the bed-bug and the sexless soldiers and workers of the white ant are examples. Their post-embryonic evolution pursues its course without variation, resembling that of the ametabolic insects. We have here a secondary, acquired metabolism; it is consequently termed *apometabolism.*

IV.

The pearl-moths, the day-flies and the dragon-flies are among the insects without metamorphosis, just as the paurometabolians, but exhibiting in their first stages new provisional organs—notably tracheal gills—for adaptation to aquatic life. In these stages they are consequently to be regarded as larvae. These larvae are comparable with the holometabolians in no other wise than by the possession of heteromorphic characteristics. Those aspects of animal transformations which are heteromorphic but not metamorphic have been designated by the happy term of *hemimetabolism.*

In presenting in this light the distinctive particularities of these organisms, we are placing ourselves in opposition to the ideas of Handlirsch. This eminent Austrian entomologist considers that these insects have preserved the primary aquatic existence of the trilobites, their ancestors, and have inherited from them their gills. In this event the pearl-moths, dragon-flies and day-flies would be paurometabolians, for their adaptation to life in the water during their younger days would not be secondary.

Everything goes to show that this cannot be. The impossibility of conceiving of the appearance of tracheae among aquatic animals, the absence of tracheal gills among the larvae of such *Paleodictyoptera* of the Primary as are known to us, the fact that tracheal gills have been acquired secondarily by the aquatic larvae of various *Coleoptera*, *Trichoptera*, *Lepidoptera* and *Diptera*—all these are potent arguments in favor of our viewpoint. And the argument is clinched by the asimilarity among the tracheal gills of the pearl-moths, the dragon-flies and the day-flies—an asimilarity sufficiently marked to demonstrate, when taken in connection with certain other peculiarities, that we have three independent adaptations, and that these insects cannot properly be united in a single group of *Amphibiotica*, as was formerly done.

These hexapods descend from terrestrial paurometabolic pterygots, and are consequently hemimetabolic.

The day-flies present in addition a singular metamorphosis, peculiar to them. The larva on attaining its complete development comes to the surface of the water, its skin splits, and it puts forth a sort of wing, completely developed, on which it flies heavily to some nearby bush. But in spite of appearances it has not yet attained the final state of the imago, but is merely in a condition of *sub-imago* subject once more to change to produce the perfect day-fly. This affords the sole known example of an insect losing its original envelope only after acquiring the power of flight.

This curious phenomenon has been interpreted as indication of a time when the pterygots maintained a succession of changes even after having reached the perfect state, just as many crustaceans and myriapods, and even a few *Thysanura*, change and continue to grow after reaching puberty. So far, however, nothing of the sort has been established among the *Paleodictyoptera* of the Carboniferous. Moreover, better reflection leads to the conclusion that a change of wings in the imago would have been an organic defect.[1] This may be inferred on numerous grounds, the chief of which is that the wing would doubtless have remained decidedly thick and heavy, and hence ill adapted to flight—not to mention the inconvenience that would result to the individual from the interruption of the animal activity at each stage of the process. Hence we prefer to believe that we have to do here with a peculiarity acquired secondarily by the day-flies, an adaptation to their special manner of emergence into the aerial medium. There would have been an acceleration of the wing development in the larva, of a sort permitting the flight of the pupa; and this premature effort is perhaps the cause of the disappearance of the maxillary appendages in the imago, as well as of the brief span of life of the latter.

To designate the combination of transformations undergone by the day-fly, Heymons employs the term *prometabolism.*

V.

Likewise hemimetabolians are the *Hemiptera* of the family *Cicadidae*, but by virtue of a larval adaptation altogether different from that found among the amphibious insects. The first state of existence of the cicadas is a subterranean one. The principal heteromorphic characteristics of the larvae, which attach

*Translated for the SCIENTIFIC AMERICAN SUPPLEMENT from *La Revue Générale des Sciences Pures et Appliqués.*

[1] Translator's Note.—Presumably the argument in the author's mind is that, being a defect and a disadvantage, such a variation could not well have been perpetuated by selection.

themselves to roots, are a transformation of the anterior legs to facilitate digging, and a late appearance of rudimentary wings, which do not show themselves until after the penultimate casting. It is customary to look upon the organism at this stage of development as a pupa. This pupa remains inactive for a certain time, as in the *Thysanoptera*, but this does not constitute metamorphosis; evolution proceeds gradually, without destruction of tissue, the animal again becoming active in due course and making its way to the surface of the ground to pass into the perfect insect.

VI.

The *Coccidae*, or scales, belong to the *Hemiptera*, their transformations considerably resembling those of the holometabolians. Like the latter they undergo a metamorphosis combined with heteromorphosis, and many zoologists have indeed been tempted to identify their post-embryonic evolution with holometabolism; but while it is true that the metamorphosis of the scales is very similar to that of the higher insects, their heteromorphosis is radically different. For it is the prosopon that is transformed into the larva among the *Hemiptera*, as in the cicada, the pearl-moth, the dragon-fly and the day-fly; while the larvae of the holometabolians, have a very different point of departure.

Berlese has consequently coined the term *neometabolism* for application to the *Coccidae*. But we agree with Hennegu~~y~~ in looking upon this phenomenon merely as one of convergence toward holometabolism, rather than of transition thereinto.

The development of the male and female among the *Coccidae* may advantageously be considered separately. At birth the male presents no heteromorphic characteristics at all. He immediately affixes himself to some plant by means of his beak, however, and then transforms, by adaptation to this sort of immobile existence, into a larva having more or less the form of a shield. In many instances he actually loses both legs and antennae; and in no case does he develop wings. At the end of this period of growth, after several castings and disappearance of the beak, there ensues a period of total inactivity, comparable with the pupa-hood of the holometabolians in that it is accompanied by a remodeling of the individual, with histolysis of the provisional larval organization. From this issues an insect without beak, but with wings, antennae and legs.

The female may present the same metamorphosis as the male, as Mayet has shown in the cases of the *Porphyrophorinae* and the *Margarodinae*; but she never acquires wings. And in the majority of cases she retains the larval structure throughout her existence, without ever passing into the state of the pupa or of the imago. So these creatures have preserved heteromorphosis as a feature of their evolution, but have lost metamorphosis.

VII.

We come now to holometabolism—a group of transformations improperly styled complete metamorphosis, which divide the life of the higher insect so happily into three periods, assuring him in the struggle for existence an almost insolent success. As a larva he is privileged to grow and accumulate energy; he brings himself to perfection in the sleep of the pupa; he attains finally the perfect state of the imago in order to reproduce himself.

The insects which we include in the category of holometabolians, in distinction from the heterometabolians comprising the balance of the *Pterygota*, are on the one hand the *Neuroptera* and the *Coleoptera*, constituting the older *Schizothoracic*[2] group, and on the other the *holothoracic*[2] members of the *Panorpidae* (the *Mecaptera*, *Trichoptera*, *Lepidoptera*, *Aphaniptera*, and *Diptera*) and the *Hymenoptera*. All these hexapods exhibit a very original group of larval characteristics quite distinct from those of the hemimetabolians. For while among the heterometabolians the prosopon or even the larva always corresponds in structure at birth to the adult, although of course frequently more or less imperfect, in the holometabolians the individual upon emergence from the egg presents an appearance altogether different from the imago; and it preserves this appearance throughout its growth, right up to its transformation into the pupa, without any external approach to the imago. It looks more like a worm than an insect; its outer covering, at least over the stomach, is singularly thin; it shuns dryness and sunlight in pursuit of a very secretive existence.

This larva, like those of the cicadas and the scales, shows no external trace of wings. The appendages, antennae, legs and cauda, unlike those of the adult, are peculiarly short and of few joints. The frontal ocelli are always lacking, and in place of the compound eyes which are found even in the prosopon and the larvae of the heterometabolians, lateral ocelli are provided of a very special structure. These are provisional organs, taking the place of the facet eyes of the imago, and they are myopic to an excessive degree. We have here a reminder of a transformation produced in the evolution of the Arachnoids, the Myriapods, and most of the *Apterygota*. Through adaptation to terrestrial life the compound eye of the aquatic ancestor of these Arthropods is decomposed into single eyes. The winged insects, on the other hand, preserve the facet eye of the crustacean, which, in the aerial medium, continues to be of service for vision at a distance.

The digestive tube of the larva is again much more simple than that of the perfect insect, the muscles are different, and in general the cells of many of the organs are larger and less numerous.

These intensely heteromorphic features are completed by an internal disposition of greatest importance. The larva possesses a reserve of embryonic cells which have not been utilized in its organic formation. These cells form the histoblasts, or imaginal disks, which are distributed throughout the animal upon the future sites of the adult organs, being at the same time in anatomic connection with the corresponding organs of the larva, wherever such exist. To the appendages and the digestive tube of the larva, for instance, are annexed the histoblasts which later will evolve to give the appendages and the digestive tube of the imago. Similarly there are imaginal disks to produce the future wings. Everything is just as though the animal had suffered an arrest of its normal development, and was remaining inactive while a certain number of these embryonic outline sketches were being directed to their destinations to furnish provisional organs.

The holometabolian larvae are therefore comparable neither with the prosopon nor with the heterometabolian larvae, since the latter are organisms whose embryonic development is terminated, which present distinctly the appendages and the digestive tube of the imago. They may be said to correspond to an embryo supposed to have emerged from the egg before having reached the prosoponic stage, and of which certain organs had been bisected while the creature was still in an indeterminate state. This explains why during all its growth the larva does not verge toward the adult except in the slow development of the imaginal discs as these go through their hidden evolutions.

Berlese has adduced several excellent arguments in favor of this point of view, which is in fact nothing but a revival of an old idea long since forgotten, according to which the holometabolian larvae are to be looked upon as embryos living outside the egg. A phenomenon of the same sort is to be found in other animals, the *Acaridae*, for instance—the mites and ticks—which at their birth possess only three pairs of legs [as against four pairs in the adult], although their ancestors, like the other arachnids, must have had four pairs at all stages of their lives.

(*To be continued.*)

[2]Greek *schizein*, to cleave; *holo*, whole.

Aerial Propulsion of Boats

ALTHOUGH little is heard of the use of aerial propellers instead of the ordinary submerged type for the propulsion of motor craft, steady progress is being made in this direction, and, what is more important, the possibilities and limitations of the arrangement are becoming more fully understood. At first sight it might be considered that a propeller which revolves in the air can never be so efficient as one turning in the water where more resistance is offered, but there has during the past few years been a great advance in the design of aerial propellers, with the result that their efficiency is now fairly good and may in certain cases exceed that of a submerged propeller. Their use as applied to motor-boats is still more or less in the experimental stage, and it is improbable that the best results have yet been attained; nevertheless, on comparative tests that have been carried out with the two types, it has sometimes been found that there is practically no difference in the speed of the boat whether a submerged or aerial propeller be employed.

SPHERES OF APPLICATION.

It may not at once be clear why there is any reason against the accepted means of propulsion, and in general it may be taken that the use of an aerial propeller is to be recommended only when there are special circumstances which render its employment specially desirable. Chief among its applications is perhaps in connection with shallow draught boats for service on rivers, the depth of which does not permit of the employment of craft with a greater draught than a few inches, or at the most a foot. There are many such waterways and rivers, particularly in the Dominions overseas, and hitherto traders on them have been unable to reap the advantages of motor propulsion, especially as in most cases only a very low speed is required with a correspondingly large propeller, altogether out of proportion to the available draught of water. One of the special correspondents in Mesopotamia has given an account of a hospital ferry in use on the Tigris, which is fitted with an air propeller and a 50 horse-power semi-Diesel engine, and "makes more noise than a minor battle."

It might be thought that if submerged propellers are unsuitable for slow shallow draught vessels the aerial propeller would be equally inefficient, since it is apparently adapted for propulsion at high speed and not at such speeds as those required for the vessels referred to, which may be no greater than three or four miles an hour. But from results attained by aerial-propelled tugs and barges it has been proved that this is not the case, and that aerial propellers can be designed efficiently both for relatively heavy low-speed craft and for light high-speed vessels of the skimmer or hydroplane type. In fact, it seems that these two classes of boat are the most suitable for aerial propulsion, and certainly by far the greatest number of examples at present in service are comprised in these categories.

As an instance of the success of aerial propulsion, a 30-foot boat, drawing only 9 inches, in which a 15 horse-power engine is installed driving an aerial propeller of about 8 feet diameter, has been in service for some time, towing some 15 or 20 shallow-draught punts, each loaded with about 2 tons. At the other extreme, there is the type of boat represented by an 18-foot skimmer, which attains a speed of 30 miles an hour, the machinery installation consisting of a 50 horse-power motor driving a two-bladed aerial propeller. These results, which may be taken as typical, appear to be equal to anything that could be attained by the employment of the same power driving a submerged propeller.

ENGINES AND PROPELLERS.

All the leading types of motor have been employed for aerial propulsion, including the semi-Diesel, paraffin, and gasoline motors, the last only for high-speed boats. As, in any case, there has to be a chain drive to the propeller, its speed of revolution can be varied within wide limits for maximum efficiency, to suit the craft which has to be propelled. This is a particularly advantageous feature, owing to the diversity of the boats on which aerial propulsion is used, and the speed of rotation of the engine does not have to be seriously taken into account when designing the installation.

It is an almost invariable rule to adopt two-bladed propellers, although there does not seem any reason why three or even four-bladed propellers should be employed in certain cases, especially where a large blade area is desirable. In one or two instances tractors have been utilized, but this arrangement does not seem to give the best results, besides possessing the disadvantage of inconveniencing those who are on board, owing to the draught of air that is created. The question of danger with a rapidly-revolving propeller also has to be considered; this is minimized, if not entirely avoided, by properly protecting the propeller with an open wire netting.

There is little likelihood that the aerial propeller will ever in any sense replace the submerged type, since in the larger number of cases of the application of the marine motor to the propulsion of boats it does not offer any particular advantages, and indeed possesses some disadvantages. But there are many instances in which the submerged propeller is unsuitable or even impossible, such as in the extremely shallow-draught craft mentioned above, and it is here that a wide field of application for the aerial propeller is opened out.—*Engineering Supplement of the London Times.*

Literacy in China

IT is difficult to secure any reliable estimates as to the extent of literacy among the Chinese of this country, but it is probably safe to estimate that not more than 10 per cent of the people of China are able to read and write. The estimates have been placed so low as 5 per cent and as high as 20 per cent. The literacy among the people of South China is greater than among those of the North. The writer has heard it said in Canton that nearly all the children of Cantonese parentage, except those of the large boat population, receive sufficient schooling to enable them to learn to read, whereas in the north of China it is unusual to find a family the children of which are all placed in school. However, the reading population in a country as densely populated as China is comparatively great, so that we find native newspapers in cities like Shanghai claiming a circulation of 10,000 to 25,000.

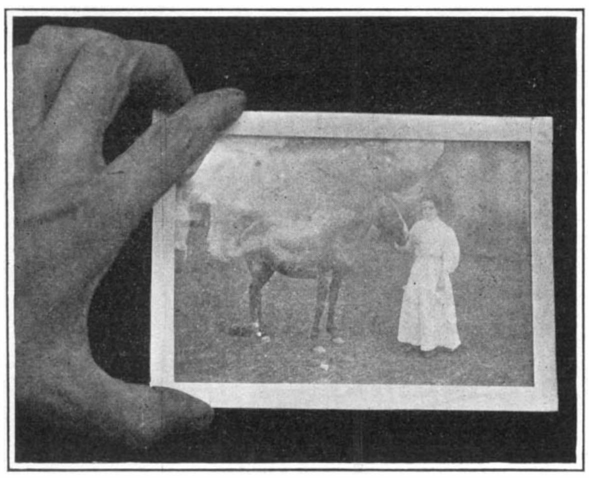
It must also be borne in mind that the native newspaper is read by a considerably larger number than the list of subscribers to that paper would make it appear. In and about Shanghai papers are sold two and three times over. Collectors go about gathering up the newspapers of the previous day's issue, redistributing them among the lower class of population.—*U. S. Commerce Dept.*

Magic Pictures

A Novel Diversion for Young People

By S. Leonard Bastin

It is possible to construct a number of novel pictures, all of which may afford a good deal of diversion. One may first of all describe the mysterious picture, quite an old idea, by the way, but one which is not commonly known at the present time. For the purpose it is needful to take two pieces of glass exactly the same size; the measurements might suitably be about four inches wide, and five or six inches long. Rather thick glass is best, although any kind would answer the purpose. See that the sheets are quite clean and then set about bordering one of the pieces with strips of cardboard,



The magic picture.

The picture is fastened behind two pieces of glass, between which is a solution that is opaque when cold, but transparent when heated.

say a quarter of an inch in width. These strips should be fastened down with the strongest glue, and it is wise to have somewhat thick cardboard for the purpose. The next step is to prepare the following solution: Over a slow fire dissolve six ounces of lard with half an ounce of white wax; finally add an ounce of clear linseed oil. The quantity indicated will be sufficient for the making of a number of mysterious pictures. In its liquid state this mixture is poured on to the sheet of glass that has been surrounded with the cardboard in such a way that there is a thin film of the solution all over, up to the level of the strips. If the glass is well warmed before the mixture is poured out, and the latter is not too hot, there will not be much danger of the sheet cracking. In a few minutes the solution will set and, when this occurs, the other piece of glass may be glued down on to the cardboard strips which have been fastened on to the first sheet. We shall now have two bits of glass closely fixed together with a film of composition between the two. It is now a good plan to bind the edges of the glass with strips of parchment or grease proof paper. This is fixed in place with glue. Next, take any kind of picture of a suitable size and fasten this by gumming the borders face downward on to one of the sheets of glass. A protecting piece of paper may be placed over the back and the mysterious picture is then complete. The workings of the picture are on the following lines. On showing the contrivance to your friends there is no sign of a picture. This is due to the fact that when the solution between the sheets of glass is cold it is dense, and no hint of a picture is to be observed. Make some excuse and hold the glass in front of a fire or over a lamp. In a moment or so the solution, which is very sensitive to heat, liquefies, and it at once becomes transparent. The picture underneath is plainly seen and everyone not in the secret is astonished at the magical appearance. When the solution cools the picture slowly fades away again, and the little experiment can be repeated any number of times.

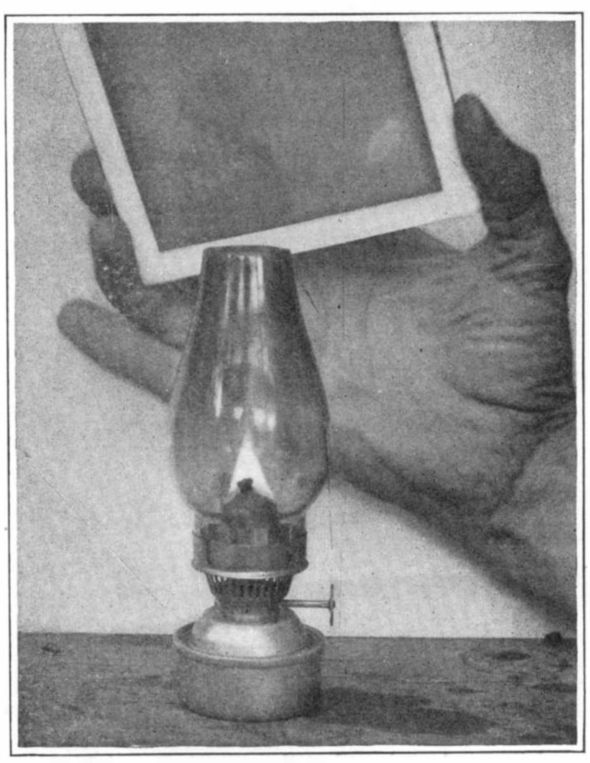
Another magical picture always causing a great deal of interest is that in which a winter landscape is in a moment changed to a charming springlike scene. In the first place it is needful to draw or secure a picture showing a typical winter scene such as snow covered fields, trees, etc. Mount this on a card and, if needful, paint the various objects in suitable colors. Wherever there is an indication of snow treat with the following solution: Dissolve cobalt powder in aqua regia (a mixture of nitric and hydrochloric acid) and allow the solution to stand for twenty-four hours. Then pour off the liquor and add an equal quantity of distilled water. Keep in a bottle which is well corked. Use this solution for painting the parts in the picture which represent snow. As applied, this mixture is quite invisible, and it does not affect the wintry aspect of the landscape. A wonderful transformation will take place when the picture is held near to a fire, or where the warm rays of the sun can fall upon it. In a few moments the fields and the trees lose their snowy burden and take on the fresh greenness of spring. The sudden change is very surprising to those who are not "in the know."

By using a cobalt solution it is possible to produce those curious pictures which change color. To get the best effect it is a good plan to deal with the print in the following manner; Select your picture, which might suitably represent the figure of a woman or a flower. Mount this on cardboard and, wherever there are clothes, or the petals of a blossom, cover these in with cut out pieces of white linen or a similar cloth. The material is stuck down with strong glue or cement. Then treat the cloth to an application of the following solution:

Cobalt chloride	1 ounce.
Sodium chloride	½ ounce.
Calcium chloride	75 grains.
Acacia	¼ ounce.
Water	3 ounces.

After application the cloth will be of a pretty rose color. If the picture is exposed to a slight heat a fine purple tinge is assumed, while a strong heat changes the material to a blue color. All kinds of puzzling tricks can be played upon people who do not understand the manner in which these magical pictures are formed.

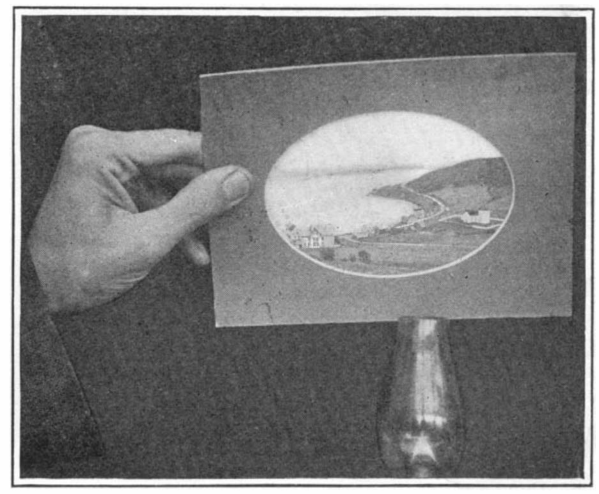
Glow pictures are very interesting little devices, easily formed, and mystifying to those who are not in the secret. About the only thing it is needful to prepare is a small quantity of the following solution. To forty parts of saltpeter add twenty parts of gelatin and the whole is dissolved in forty parts of warm water. When the mixture is cool it will set somewhat in jelly fashion, but it is easily liquefied for use as described later. This is how the actual pictures are prepared.



Developing the magic picture.

To bring the picture out it is only needful to hold near a lamp or fire.

Take sheets of white paper, which should be somewhat thin, similar to that used for typewriting. Now slightly warm your solution by standing the bottle in a cup of moderately hot water. Take a clean pen and dip this into the mixture, then sketch out the picture, design or lettering that is desired. The picture should not be too elaborate, and it is important that all the lines should connect. The finishing line must be carried right down to the corner of the paper, and the end of this might be marked with a tiny pencil cross. When the lines that have been made are dry (which will be in quite a short time) steps must be taken to mount the paper in such a way that there will be an air space between it and the table upon which it is resting. The best plan is to cut out some strips of cardboard, as shown in the accompanying photograph, and stick these with paste round the borders of the sheets. The glow pictures are then ready for displaying and it is interesting to notice that the lines on the paper are practically invisible, so that the design appears to come up almost



Winter changed to spring.

In this picture the fields are at first white with snow, but on being warmed the green leaves of spring appear.

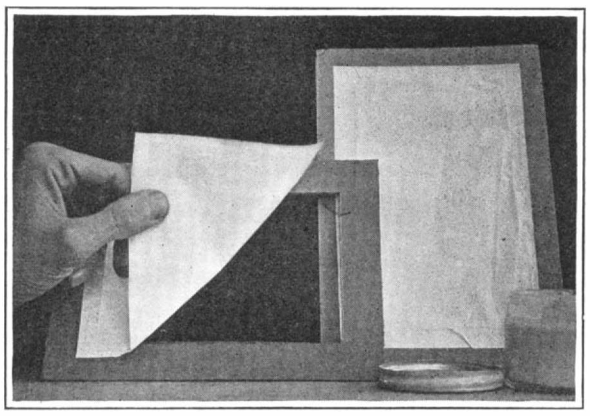
from nowhere. This is how the device is set going. Put the sheet of paper cardboard strip downward on to a flat surface, such as a board or wood. Next strike a match and, after allowing this to burn for a minute, blow it out. You will then have a glowing end and this should be applied to the termination of the line which has been marked with the pencil cross. At once a trail of smoldering fire is started which follows the lines marked on the paper. The burning does not finish until the picture has been entirely worked out, that is, provided all the lines connect as previously indicated. At no time does the paper flame, and this pretty little experiment is an absolutely safe one, even for children to carry out.

New Telephone Sound Augmenter

I venture to herewith send description of a new novel sound augmenter I have invented especially for telephones, gramophones, phonographs, etc.

It consists of a special microphone sensitive to such a degree as to respond to sound inaudible to human ear, yet capable of carrying heavy currents and so reproducing by aid of ordinary Bell receiver, augmented in volume sufficiently loud, if necessary, to fill a large hall.

In essentials the microphone consists of a circular elastic disc covered with an electrolytic deposit of iron; round the periphery of this elastic disk radiate a number of elastic cords covered with metallic fillings electrically in contact. The number of these cords and diameter of same vary with the size of microphone and current it is intended to carry. These cords are electrically connected to two half-plates of brass whose distance apart can be determined by screw tension. The microphone is fitted in a small adapter, which can be clipped on the front of any ordinary telephone receiver, and is self-contained and electrically connected, requiring no interference with ordinary telephone connections, which, of course, would not be permitted by telephone authorities. The action of the instrument in the case of an ordinary telephone receiver is as follows: The half-audible or inaudible sound (and what person who has ever used a telephone does not know the meaning of these terms) is at once responded to by the delicate elastic iron-covered disk, which vibrates, setting up vibration of the elastic metal-covered cords, which instantly vary the resistance in a small dry battery circuit, which in turn, containing a small watch receiver, responds in volume of sound, in the case of an ordinary instrument speech being audiole a dozen



Preparing a magic glow picture.

The prepared sheet should be mounted so that it is somewhat raised.

feet away from the instrument, and by a suitably wound receiver, a large microphone, and a current of 3-12 amperes sound can be easily obtained to fill a large hall. In case of phonographs and gramophones the attachment is connected to the sound arm coming from the sound box diaphragm, and according to size of apparatus produces the record powerful in tone and magnitude, minus a very large percentage of false metallic clang so characteristic of phonograph sounds. —*C. Mayfield, in The English Mechanic.*

Meteorites: Wonderful Messages From the Sky

The National Museum has recently issued a handbook and descriptive catalogue of the meteorite collections in the museum, written by Dr. George P. Merrill, head curator of geology, from which the following is an abstract:

Although meteorites have presumably fallen since time immemorial, a great deal of scepticism was felt at first by both the popular and scientific minds regarding the possibilities of stones falling from space. So great was this scepticism that the examples preserved in the public museums were once hidden or discarded, the custodians fearing to make laughing-stocks of themselves. In the few early recorded cases where meteorites seen to fall were recovered, they were regarded as objects of reverence and worship. A stone which fell in ancient Phrygia, in Asia Minor, about two hundred years before Christ, was worshiped as Cybele, the mother of the gods. Another, which dates back to the seventh century, is still preserved at Mecca, where it is built into the northeast corner of the Karaba and revered as one of the holiest of relics. The great Casas Grandes iron, weighing about three thousand pounds, now in the national collections at Washington, was found in an ancient Mexican ruin swathed with mummy cloths in a manner to indicate that it was held in more than ordinary veneration by the prehistoric inhabitants.

The earliest known undoubted meteorites still preserved are those of Elbogen, Bohemia, and Ensisheim, Upper Alsace, Germany; the first mentioned is iron, the second a stone. The iron was found somewhere about the year 1400 of our era, but its meteoric nature seems not to have been fully established until 1812. It has, however, for several hundred years been preserved in the Rathhaus at Elbogen. The Ensisheim stone seen to fall on November 16, 1492, about the time Columbus made his discoveries, was accompanied with a loud crash like thunder. Portions of this stone are to be seen in the National Museum exhibit.

Occurrences so well authenticated as the last should have gone a long way toward convincing the scientific world, at least, but such was not the case, and as late as 1772, a committee presented to the French Academy a report of the examination of a stone seen to fall at Luce, four years previously, which they asserted was but an ordinary rock that had been struck by lightning.

In 1794, the German scientist Chladni brought together all the accounts of the supposed meteorites, calling the attention of the scientific world to the fact that several masses of iron had in all probability come to the earth from the outer space. He referred especially to the now well-known Pallas iron, which was found by a Cossack in 1749, among the rocks in the highest part of a lofty mountain near Krasnojarsk in Siberia. Chladni argued that this iron could not have been formed under the influence of fire, and held that it could not have been formed where found, or by man, electricity, or an accidental conflagration. Hence, he inferred that it had been projected from a distance, and, as there were no volcanoes known to eject iron, and none in that vicinity, he was compelled to regard it as actually having fallen from the sky. During this same year an observed shower of meteoric stones fell near Siena, Italy, and the following year a 56-pound stone fell out of a clear sky almost at the feet of a laborer in Yorkshire, England, while in 1978 many more stones fell at Krakhut, near Benares, India.

The scientific mind was, however, slow in accepting these proofs, but fortunately a shower of stones, upward of three thousand in number, occurred about April, 1803, in the neighborhood of L'Aigle near Paris. The circumstances of this fall were fully investigated under the auspices of the French Academy of Sciences, the report of which was of so conclusive a nature as to forever set at rest all doubts concerning their celestial origin.

The fall of a meteorite is usually accompanied by noises variously described as resembling the fire of musketry, cannonading, or even thunder. If the fall takes place during the periods of darkness it is also accompanied by a flash of light and followed by a luminous rocket-like trail. These phenomena are due to the rapid passage of the objects through the air, and a consequent rise in temperature, sufficient to produce fusion of the outer surface and even ignition, thus giving rise to the thin, dark, glass-like crust which is found to cover all stony meteorites. The time of passage through the atmosphere is, however, too short to permit the heat to penetrate to great depths, and nearly all meteorites are quite cool, or scarcely warm, on reaching the surface of the ground. It is to the sudden rise in temperature and pressure of the atmosphere that the breaking up of a meteorite and its reaching the ground as a

A magic glow picture.

The lines are drawn with a saltpeter solution, which is invisible.

shower of fragments rather than a single individual is due.

We have little to guide us in estimating the speed at which a meteorite reaches the earth and its consequent power of penetration. The velocities as given by various observers vary between 2 and 45 miles a second. The greatest recorded depth of penetration of a meteoric stone is that of Knyahinya, Hungary, where a 660-pound stone penetrated to a depth of 11 feet. On the other hand, still heavier masses have been found under such conditions as to lead one to infer that they scarcely buried themselves.

All statements relative to the temperature of meteorites immediately after reaching the ground must be accepted guardedly, owing to their extremely contradictory character. Some stones which fell in Styria in 1859 are stated to have remained in a state of incandescence for over five seconds, and for a quarter of an hour were too hot to be handled. On the other hand, the Dhurmsala stone is said to have been intensely cold when picked up immediately after falling.

Reports of the setting of fires by the falling of meteorites must also be taken with some degree of allowance. In the cases of both Allegan and Winnebago falls, the stones struck on the dried grass, which was not charred in the least, and one of them fell on a stack of dry straw without igniting it.

The possibility of human beings and animals being struck by these falling bodies has been discussed, and several instances dating back to periods from 1511 to 1674 are mentioned in which persons were killed. The absence of any recorded instances of this sort within

The rag picture.

How the variously treated pieces of rag are put into position. The girl's dress changes color according to the degree of heat applied.

more recent times, however, renders the occurrences doubtful.

Upwards of 650 falls and finds of meteorites have been reported, representatives of which have found their way into museums and private collections, and there preserved for study and investigation. The largest known meteoric mass is that brought by Commander Peary from Cape York, Greenland; this weighed 73,000 pounds. The next largest lies in the plain near Bacubirito in Mexico, and has been estimated to weigh some 50,000 pounds, while the third is that of Willamette, Ore., weighing 31,107 pounds. These are all iron meteorites. The largest known individual aerolite or meteoric stone is that of Knyahinya, Hungary, weighing some 550 pounds, now in the Vienna National Museum.

Dr. Merrill says in conclusion that all known meteorites were produced by the action of heat, and have yielded no traces of animal or vegetable life, although parts of their peculiar structures were at one time mistaken for organic remains.

Natural History of the Eel

Dr. Johs. Schmidt, in vol. xxiii. of *Rapports et Procès-verbaux du Conseil International pour l'exploration de la mer*, gives a further contribution of his studies on the natural history of the eel. The paper deals with the question of the existence of smaller species" or "races" of the European eel, and with the distinguishing features of this species, of the American and of the Japanese eel. The characters investigated include the number of vertebrae, the number of rays in different fins, and the number of branchiostegal rays. The conclusion arrived at is that, while the three species investigated are clearly marked the one from the other, it has not been found possible to distinguish between different "races" of the European eel. The most convenient character is the number of vertebrae. The author brings forward a point of considerable biological interest by comparing the condition found among the eels with that found in the viviparous blenny (*Zoarces viviparus*), a species having about the same number of vertebrae as the eel. He finds that samples of Zoarces taken from closely adjacent localities in Danish waters may differ one from another as regards number of vertebrae to a higher degree than does the European eel from the American eel in respect of the same character, and that, whereas *zoarces viviparus* in the north of Europe is divided up into numerous distinctly different stocks or populations according to locality, all the eels of Europe are identical. This difference the author considers must be due to the fact that all European eels have the same origin in the spawning grounds of the Atlantic Ocean. The blenny, on the other hand, is viviparous and has no pelagic stage, so that it is highly localized, and specimens collected, for instance, in the inner waters of a fjord may have a lower number of vertebrae than those taken at the mouth. Whether this is due to "genotypic differences" or to the immediate effect of varying external conditions, the author hopes to make a matter of direct experiment.—*Nature.*

Towing At Sea

It is not so many years that commercial ocean towing was not considered practicable, but experiments proved the contrary, and as experience was gained longer voyages were made. The towing of big barges, specially constructed for the purpose, across the Atlantic has been not at all unusual of late, and now the report is made that a big American tank vessel has arrived safely at Shanghai, having in tow a large barge, both laden with oil. The distance covered is said to be 12,465 miles, which is a record for ocean towing.

The Decay of Metals*

Certain Changes in Character That Are Liable to Occur

By Mr. Cecil H. Desch, D.Sc., Ph.D.

THE present paper is intended to describe certain changes of an unfavorable character which take place in metals and alloys in the course of use or storage, including under the name "decay" such changes as proceed completely through the mass of the metal, and are thus of a more thorough and far-reaching character than mere superficial corrosion. It is proposed to include three classes of changes; namely, disintegration due to internal molecular change of the kind known in chemistry as allotropic; disintegration due to the existence of internal strains and consequent instability; and decay brought about by an external agent, the examples of the last class being essentially cases of corrosion.

The first class is the simplest in principle. As an example, the behavior of tin in cold climates may be considered. While ordinary white tin is a crystalline, apparently stable metal possessing considerable toughness, it is known to undergo a remarkable change under certain conditions. In cold countries, such as Russia, where tin is largely used for roofing and other purposes, it sometimes happens that a roof or other object of tin will suddenly begin to decay in a peculiar fashion. Small spots make their appearance on the surface, at each of which a mound of gray powder becomes visible, and in a short time each spot becomes a hole, which rapidly perforates the metal. The most remarkable feature of the change is that whenever a few particles of the gray dust are carried by the wind and fall on to another piece of tin, a similar spot of decay starts on the surface of sound metal where it is touched by the dust. In this way the disintegration may spread through a district, until not a piece of sound tin is left. Once having begun, this mysterious form of decay proceeds at an increasing rate, as the contacts between sound and decayed tin multiply. From the appearance of the original "eruption," and the way in which the infection is carried by "germs," the whole process has a curious similarity to an infectious disease, and has, in consequence, received the name of the "tin plague."

Organ pipes in Central Europe are frequently of tin, and the same disintegration has been observed in their case. It is also recorded that a large stock of military buttons of tin was held in one of the Russian stores at one time, and when the buttons were to be taken into use, the whole stock was found to have crumbled to a gray powder.

This disease of tin has been studied in detail by Prof. Cohen, of Amsterdam, who has shown that the change is an allotropic one, and that the temperature at which white tin changes into the gray modification is 18 deg. C. According to this—and the result has been abundantly confirmed—tin is in an unstable condition whenever the temperature is below 18 deg. C., that is, throughout by far the greater part of the year even in this country. However, the liability of the metal to change spontaneously is very small, and at ordinary temperatures tin may be regarded as practically stable. The lower the temperature, the greater the likelihood that change will take place, so that it is only in cold countries that the conditions are continuously favorable for its occurrence. The hastening of the transformation by contact with the new modification is a usual condition of allotropic changes, and it is only in the manner of its occurrence that the deacy of tin differs from other allotropic changes which are familiar in the laboratory.

It is very probable that tin is capable of undergoing another transformation, quite independent of that just mentioned, at higher temperatures. Tin worms used as condensers in distilling apparatus occasionally decay at the point at which they are heated to the temperature of boiling water, in such a way that the metal acquires a columnar structure, and breaks up into fragments, transversely to its thickness. The writer has examined such a condensing worm, and has found that the change is in no way one of corrosion, but that the tin remains chemically uninjured, although losing its strength almost completely. Several observers have recorded decay of this kind, but it has never received systematic investigation as has the corresponding change at low temperatures.

It is probable that lead is also liable to undergo allotropic change, under conditions which are not as yet well defined. It is certainly the case that lead sheets will sometimes break up into separate crystals, especially where subjected to the action of solutions containing lead salts. The process is not simply one of chemical corrosion, as the crystals that remain are pure lead, but is rather to be regarded as one of allotropic change. accelerated, as such changes are known to be, by the presence of an electrolyte. It does not appear to be connected with the impurities in ordinary lead, as the writer has found that it takes place with equal readiness with common sheet lead or the purest assay foil.

Some of the light alluminium alloys are liable to disintegrate spontaneously, falling completely to powder owing to internal molecular change, but fortunately none of the alloys in common use behave in this way, although the occurrence of such a condition throws a certain suspicion on all such alloys until they have been systematically tested for stability under varying conditions.

Another type of decay is due to the movement of gases dissolved in the metal. We may pass over such cases as the "gassing" of copper, the chemical cause of which is well known and the condition preventable, but a reference may be made to the behavior of nickel wires when used as resistances in electric furnaces. Prolonged use results in the development of brittleness, the cause of which has been explained by Prof. Carpenter. Nickel invariably contains dissolved gases, and these are set free during the heating of the wire, while the cooling between two periods of use is insufficiently slow to allow of the complete reversal of the process, so that a part of the gas remains undissolved between the crystal grains of the metal. Repeated alternations of heating and cooling, the outer layers of the wire always cooling before the interior, result in the loosening of the structure, so that in time the crystal grains are completely separated, and the wire crumbles. The process may be followed under the microscope.

The next form of decay takes place in metals which have been severely cold-worked. Brass rods and tubes which have been hard drawn are occasionally liable to "season-cracking," the cracks making their appearance either during use or in storage, being specially liable to occur when the rods are transferred to a warmer climate, or exposed to slight corrosion. Numerous failures of brass and bronze from this cause have been recorded during the last few years from the Catskill Aqueduct, where the decay has occurred on a very large scale. The explanation lies in the existence of severe internal stresses in the metal, owing to the unequal deformation of the inner and outer layers. The cracks are very commonly transverse.

Although season-cracking is generally hastened by exposure to temperatures above the normal, yet the reverse condition, of heating preventing this form of decay, may sometimes occur. The writer once had to deal with some yellow metal rods which were intended for use as the shafts of stirrers in a vat containing a boiling chemical solution. Those rods, which were placed in the hot solution as soon as they were received from the makers, remained sound and retained their strength, while those which were placed in store broke into several pieces. Evidently the heating in the boiling solution sufficed to anneal the alloy and relieve the stress. Very frequently the cracking is started by superficial corrosion, the attack of the corroding agent separating the crystal grains of the surface layer, and so acting in the same way as a crack. Ammonia is known to cause season-cracking in brass, but many other agents will act in the same way, while the previous existence of internal stresses in the metal is always presupposed. When the chemical agent is one which acts rapidly, a remarkable effect may be produced. The loosening of the texture at the surface may be so rapid that cracking set in immediately, with almost explosive violence. Very hard-drawn rods of brass or bronze will sometimes fly to pieces on being touched with a solution of a mercury salt, or of ferric chloride. Thin sheet metals which have been "spun" into shape are particularly liable to crack from this cause.

Severe stresses in a metal may, by opening up cleavages in the crystal grains, increase the liability to corrosion, such cleavages affording a path along which the corroding agent may find entry, even though the action may not have gone so far as to produce cracks.

It is well known that corrosion is accelerated by the contact of dissimilar metals. As a single metal in the annealed and the cold-worked conditions differs in its electrical properties, the contact of the two favors corrosion, so that a metal which is locally cold-worked is particularly liable to corrode. For this reason the corrosion of a cold-rolled metal takes place in such a way that the rolling lines become clearly visible, pitting or grooves appearing in a direction parallel with that of rolling.

The corrosion of alloys which contain two or more solid constituents or phases is of a special character. An instance may be taken from the "graphitization" of iron pipes, a form of decay to which cast-iron is liable when buried in the ground. The iron becomes so soft that it may be cut with a knife, while its external form and appearance remain unchanged. Microscopical examination shows that the ferrite has been almost completely removed, the cemetite and phosphide eutectic remaining unaltered, while the graphite either retains its original character or, in some instances, is converted into a white substance, which borders the lamellae of graphite, and has the appearance of a carbide. Here the electrolytic difference between graphite and iron has played a part in determining the course of the process of corrosion.

Another illustration of the course of corrosion in an alloy containing two solid phases may be taken from the light aluminium alloys. Such an alloy as duralumin contains small particles of a hard constituent, embedded in the softer ground-mass of solid solution. Corrosion of such an alloy usually starts in the form of minute pitting, and the pits are seen under the microscope to be quite close to the minute masses of the compound, and parallel to them in outline. The formation of local electrolytic couples, determining the way in which corrosion takes places, is here obvious.

This type of decay is most clearly observable in those alloys of copper and zinc which consist of two solid phases, the yellow metals, including Muntz metal, Delta metal, the inappropriately-named "manganese bronze," and similar alloys. The two constituents, known as alpha and beta, contain different proportions of the component metals. When corrosion begins, the beta, which is the richer in zinc, is the more readily attacked. The zinc is dissolved out of the alloy, and the residue of spongy copper soon oxidizes, so that a porous mass of red copper oxide comes to occupy the parts which originally consisted of beta. When the whole of this constituent has been removed, the attack extends to the alpha, which is in turn deprived of its zinc and converted to spongy copper and oxide. This takes place in such a way that the object may retain its external form unchanged, although it may consist merely of brittle oxide. This form of decay was first studied in detail by Prof. Arnold in the case of brazing metal. It is remarkable that the zinc may be removed from the beta constituent to a considerable depth before any change takes place in the alpha. A section through a bolt of yellow metal which has been corroded in sea water often exhibits three zones: An outer, in which the removal of zinc has been complete, so that nothing but oxide remains; an intermediate, in which only the beta has been destroyed and the alpha remains; and an inner core of still uncorroded metal. Instances of this form of corrosion were described by Milton and Larke in a well-known paper. The beta constituent, being richer in zinc, is naturally more electro-positive than the alpha, and serves as a cathode in the initial stages of the corrosion, whilst the reversal at a later stage shows that the alpha is then anodic toward the copper. It is not at first sight clear why there should not be a position of equilibrium, at which the beta would have so much zinc removed as to have the same composition as the alpha, so that an electro-chemical difference would cease to exist. That this does not occur is no doubt due to the loose and porous texture of the metal after the removal of zinc, which makes a true equilibrium impossible.

An unusual example of this form of decay is a valve spindle which has corroded in such a way as to have separated into two concentric parts, an inner core of almost sound metal, and an outer sleeve of dezincified metal, the intermediate zone having been completely dissolved away. In the absence of detailed information as to the exact conditions of the corrosion, the only explanation which suggests itself is that the original rod was cold-worked, and that a sufficient difference of electrolytic properties existed between the inner and

*Transactions of the Institution of Engineers and Shipbuilders in Scotland.

outer zones to limit the initial corrosion to the intervening layer. Having once started in this way, the porosity of the resulting mass would tend to localize the corrosion during the continuance of the process.

In view of the fact that the physical character of the products formed in the initial stages of the corrosion process plays so important a part in determining the subsequent course of the change, the writer, together with some of his students, has carried out investigations by means of a small laboratory apparatus of special design, in which a specimen of metal of the size usually employed for microscopical examination is subjected to controlled corrosion under the influence of an applied electromotive force. It has been found that conclusions arrived at in this way may be applied with some confidence to cases of corrosion occurring under the conditions of practice. A few of the principal conclusions may be mentioned.

The removal of zinc from brass by the action of electrolytes always proceeds in the first place along the boundaries of the crystal grains. Moreover, the boundary between unaltered metal and spongy copper is invariably sharp—that is, there is no zone of appreciable thickness in which the metal contains a proportion of zinc which is less than that of the original crystals, but greater than zero. It is a point of some theoretical interest that twinning planes behave in this respect like crystal boundaries.

The corrosion of condenser tubes in sea water is a problem of great interest to engineers, and one which lends itself to this method of investigation. The slides exhibited show that there is no difference between the structure of tubes which have been corroded in actual service and similar tubes which have been corroded rapidly in the laboratory by the electrolytic method. In both cases the first stage is the removal of zinc, and the formation of copper oxide is a secondary effect, due to the oxidation of the spongy copper. In both cases, also, the boundary between corroded and uncorroded metal is sharp, even under a high magnification.

One factor which is proved by such experiments as these to be of great importance is the physical condition of the product of corrosion. This fact may be illustrated by reference to the familiar instances of iron and zinc. Both are attacked by moist air containing carbon dioxide, but while iron forms a loose, incoherent mass of rust, through which more moist air readily finds a way, so that corrosion may proceed unchecked, the layer of white salts formed on zinc is tough and adherent, and serves as a protective varnish, preventing the entrance of air and bringing the corrosion to a standstill, provided that the layer remains unbroken. The conditions under which the attack by chemical agents takes place affect the character of the surface film to a remarkable degree. Thus aluminium forms a tough, adherent film by atmospheric corrosion in temperate climates, but in tropical climates the film is much more porous, so that aluminium drinking vessels in the tropics acquire a foul taste, similar to that acquired by porous earthenware, and from the same cause. Again, when aluminium is rubbed with mercury, the oxidation in ordinary air is so rapid that the metal becomes hot, and the oxide forms a loose, incoherent growth resembling a vegetable rather than a mineral substance.

It is well known that the addition of one per cent of tin to either brass or Muntz metal greatly increases the resistance of the alloy to corrosion by sea water, and this addition is commonly practiced. The reason is not immediately obvious. The quantity of tin cannot be supposed to alter the electrolytic potential of the alloy to so material an extent, but yet the influence of tin is often regarded as electro-chemical. Examination by the method just described shows that the protection afforded by tin is really mechanical in its character. Tin does not hinder corrosion in its earliest stage, but the layer of basic tin salts which soon forms is peculiarly tough and adherent, and can only be removed with some difficulty, so that it acts as a protective varnish. The presence of two per cent of lead, recently recommended for the protection of condenser tubes, has a similar effect. In this case, it is of interest to note that one per cent of lead is insufficient for the purpose, as the basic salts are then too porous to protect the underlying metal, and that a larger quantity is necessary. Lead actually promotes the corrosion in the initial stage of the attack on brass, and the subsequent arrest is, as stated above, purely mechanical in its nature.

Gun-metal has been examined in the same manner. This alloy normally consists of two constituents, a homogeneous solid solution known as alpha, and isolated masses of a hard, white substance known as delta, and containing a relatively higher proportion of tin. During ordinary corrosion, only the former is attacked, and the hard particles remain in relief on the surface of the section. Only when the corrosion is very rapid, as when a large current is passed, does the attack extend to the second constituent. Tin being much less electropositive than zinc, there is no such preferential removal of tin from gun-metals during corrosion as would correspond with the removal of zinc from brasses.

The memoir of Milton and Larke, to which reference has already been made, contains the description of a case of decay in gun-metal which has followed a different course from that just described. Examination under the microscope shows that the greater part of the alpha constituent has remained unattacked, while the delta masses have been replaced by copper or are represented by cavities. The metal was in the form of a steam valve, and the most probable explanation of the anomalous decay seems to be that the alternate heating and cooling, owing to the very different coefficients of expansion of the alpha and delta constituents, produced a loosening of the texture, so that the entering steam, probably carrying corrosive gases, found its way between the crystal grains and produced the channels. The removal of tin is curiously complete, the decayed portion of the valve showing little else but copper in the channels.

Animal Ecology

Animal ecology is the most recent branch of zoology and is now only in the initial stages of its development. We may define it as the study of animals in relation to their environment.

Plant ecology is a good deal older than animal ecology, and has stood as a separate branch of botany for the past fifteen years. This is undoubtedly due to the simpler and far more uniform structure of plants as compared with animals and to the fact that most plants are stationary and thus their relation to their habitat is far easier to work out.

Animal ecology is an extremely broad subject. The study of the environment requires some knowledge of geology, meteorology, soil physics, soil chemistry, and of plant ecology. Plant ecology requires a knowledge of systematic botany, plant physiology and plant histology. The study of the animals in the environments calls for a knowledge of systematic zoology, anatomy, physiology, embryology and animal psychology. It is of course a field study and this means that a knowledge of field work, with its incident familiarity with equipment, camp-life, wood-craft, chart-reading, photography, collecting, and note-taking, is a prerequisite.

Animal ecology is a dynamic study, not a static one. The compiling of a list of the species of animals of a region is not animal ecology. The compiling of a list of the dominant forms of a particular habitat is only a beginning or basis for ecological work. Real ecological work entails the working out of the relation of each dominant species to its environment, and to every other dominant species, since all other species in a habitat are part of the environment of any particular species. It entails also the study of the changes continually, very slowly often, it is true, but still continually, taking place in the environment. This change by which one habitat gradually passes into another is termed succession and may be illustrated by considering a pond. In the early stages we have clear shores and clear bottom, and consequently we find animals characteristic of such habitats. In the next stage Chara is present and with it certain species of animals. Next we have submerged aquatic plants present, such as Myriophyllum, Elodea, and Potamogeton, and again we find a changed fauna. Then the emerging vegetation, such as rushes, sedges and grasses, gradually grows out from the margin until the pond is converted into a marsh. In this stage we find again a different group of animals, and we have two strata—an aquatic stratum and an aerial stratum. The marsh is in turn invaded by trees and with them come other characteristic animal groups. Gradually the marsh is converted by the accumulation of vegetable debris into dry land, and passes through several stages, each marked by certain characteristic animal forms, into the climax formation of the region. This climax formation varies in different parts of the country. Over a large part of southern Ontario it is the Maple-Beech forest, over other large stretches of Canada it is the Spruce-Birch forest.

A climax formation is that formation towards which all other formations tend, and this particular type of succession, in which several quite distinct habitats all converge towards one formation, is termed convergence. In southern Ontario, for example, habitats as diverse as ponds, peat-bogs, dry thickets and sand-dunes all converge towards the Maple-Beech forest. Further, this climax formation is, as the name implies, the last and stable formation.

Another kind of succession, which is well marked in some habitats, is seasonal succession. In this case a certain area may be an aquatic environment early in the season and a terrestrial one later on.

The idea of succession is expressed even on a smaller scale, as in the succession of beetles in a single tree. Certain wood-boring beetles attack living trees and by their attacks kill them, thus paying the way for other species which live only in recently killed trees, while these in turn are suceeeded by species which live in wood which is more or less decayed.

One important difference between the ecology of plants and animals is that the former respond to the influence of the environment by a change in structure, the latter by a change in behavior.

A fact which complicates animal ecology is that animals may belong to two or even three habitats. Thus an animal may breed in one habitat and feed in another; or it may pass its first stages in one and its adult life in another, only visiting the first habitat again for oviposition. The turtles, which feed in the water and lay their eggs in dry sandy banks, are an example of the first class, and numerous insects belong in the latter category.

In aquatic environments the factors which we have to consider are the amount of salts, oxygen, and carbon dioxide, light, temperature and materials for food and abode. In terrestrial habitats the factors are temperature, light, humidity, air pressure, air currents and materials for food and abode. The best single criterion for a terrestrial environment is the evaporating power of the air, as it takes in all the factors except the last two.

In making our main divisions of habitats one factor must be taken and the one which gives the most practical arrangement is the amount of water. On this basis we classify our formations, which is the name given to the main ecological divisions. The formations are then divided into asociations, and the associations into consocies. In making these two latter divisions different factors have to be taken into consideration in different cases. As an example of these groups we place all fresh-water animals in the Hydrotheric Formation, those of streams belong to the Potamicolus Association, and if they live in pools in these streams they constitute the Pool Consocies. A consocies is thus the unit in animal ecology, much as a species is the unit in systematic zoology. In some associations, as for instance in the associations of the Hylitheric Formation, or Forest Formation, stratification comes in. Thus in the Maple-Beech Association we have a subterranean stratum, herbaceous stratum, shrub stratum, tree-trunk stratum and tree-top stratum, and each stratum has its consocies.

From this brief outline it can be seen that animal ecology is essentially a live subject, a study of living animals under natural conditions, that it is a complex but extremely fascinating study, and that results obtained by it will act as a balance-wheel on purely laboratory studies of animals.—*A. B. Klugh in Queen's Quarterly.*

By Rail to Ceylon

Engineers have long contemplated the sandbanks stretching between India and Ceylon as affording the route for the railway that must ultimately connect the beautiful isle of the Sinhalee with the Indian mainland.

But just how to make Adam's Bridge a bridge in fact as well as in name has baffled several generations of engineers. The gap is not as long as it was a few years ago, thanks to recent skilful seaward extensions of the terminal points of the railways. In fact, the break now measures barely twenty miles, since the South Indian Railway has been extended to Dhanushkodi, the Ceylon State Railway meanwhile being brought to Talaimannar, at the oposite side of the shallow strait. Excellent, though these extensions are, the desire is now, as always, to abolish the ferry-boats entirely, and to secure through running trains.

With this object in view, a scheme has been worked out whereby a connecting railway line should be laid on a solid embankment to be erected on the sandbank known as Adam's Bridge.

This causeway would extend about twenty miles, of which about seven miles would be built upon the dry land of the various islands, and thirteen miles in water. The section through the sea would be constructed on a double row of reinforced concrete piles driven into the sand. Behind the piles slabs of reinforced concrete would be slipped into position, the bottom slabs being sunk well into the sea-bottom, and the space enclosed by the slabs filled in with sand. The top of the concrete work would be carried six feet above high-water. The estimated cost of the work is £740,000.—*London Daily Telegraph.*

Official photograph from the London Illustrated News.

One of the long range field guns, recently built by the British, in action at the front in France.

The Big Guns in the War

The New Artillery Now Being Used By the Allies

A HUMOROUS paragrapher in a daily paper has said that "the art of war is artillery," and this appears to be literally true, for without its powerful artillery, against which Belgium and France had nothing to oppose, the great advance of Germany in the early days of the war could not have been so readily accomplished, nor the rolling back of the Russians from East Prussia and the borders of Hungary. With the great 42 centimeter howitzers that Germany so dramatically disclosed the famous armored turret forts of Antwerp, of which so much had been expected, were crumpled up like paper toys, and the supposedly impregnable masonry fortresses at other points were reduced to useless heaps of debris, and from distances that were utterly beyond the reach of any guns then possessed by the Allies. And it was not alone the great size of these guns, with the immense shells they threw, that caused consternation among the French and Belgians, but the facility and rapidity with which they were transferred from place to place, easily keeping pace with the advancing armies, for which they opened the way, for before this war began other nations had generally considered that the 6-inch howitzer, with its little 120-lb. projectile was the heaviest weapon required by an army, and the largest that could be practically handled in the field. Now, however, howitzers of from 11 to 16 inches are employed by all of the countries engaged in this great conflict and are being readily transported in the field.

It may be remarked that the idea of using such enormous pieces did not originate with Germany, but with the Japanese, during their campaign in Manchuria against the Russians; but German stratagists quickly grasped their value, and immediately began to develop the idea, not only working out the details necessary to make the use of guns of large size practical, but also solved the additional and difficult problem of transportation, without which the new methods of warfare would be impossible.

It is rather difficult, with the information available, to exactly classify the big guns used by Germany and Austria in their siege operations, whether they should be called mortars or howitzers. The true howitzer is a weapon having a barrel considerably shorter, in proportion to its bore, than the ordinary type of cannon, but still much longer than a mortar. On the other hand, of late years, mortars have been growing longer. Both the howitzer and the mortar must be aimed at a much higher angle to attain a practical working range than the long cannon, so that in actual use the difference between the two classes of arms appears to come down to a matter of the degrees of elevation at which they are usually fired. All things considered, it would seem that the new heavy guns of Europe may be termed howitzers, for even with long guns there is a growing tendency to operate them at greater angles of elevation than was formerly considered desirable, even on ships, where special considerations have been supposed to limit the elevation.

The big guns used by the Germans at the sieges of Liege and Namur are said to have had a bore of 12 inches, and they fired shells weighing from 800 to 1,000 pounds a distance of eight miles. These were the guns so frequently referred to in the reports from abroad as "Busy Berthas," a nickname alluding to Frau Krupp; and it has been rumored that still bigger howitzers have been designed, having a bore of 52 centimeters, or 20.5 inches, but so far they have not materialized.

The Austrian "Skoda" howitzers, built at the Skoda works at Pilsen, in Bohemia, are credited with a bore of 42 centimeters, or nearly 17 inches. The shells fired by these giants are said to weigh 2,800 pounds, and it has been claimed that they kill every human being within a radius of 150 yards. These short, but heavy, guns use only explosive shells, for it is said that experience during the war has demonstrated that shrapnel is not effective when fired at such high angles as are necessary when using this class of artillery.

As has been said, the range of these German and Austrian weapons is about eight miles, but some of the guns of large caliber used by Germany have had a far greater range. Thus in the bombardment of Dunkirk shells were dropped into the city from a distance of 22 miles, and these are said to have been of 12 or 15 inches bore. To attain such a range the guns used must have been of much greater length than any that have been heretofore referred to, and it has been estimated that they were fired with an elevation of over 30 degrees. As far as is known, however, very little has been done at such ranges since the Dunkirk incident, and there is no definite information in regard to the character of the guns used.

One of the interesting questions that will not be answered until after the end of the war is in regard to the life of these big guns, although all of the contending nations will individually know all about it long before that time, as all are now provided with weapons of from 10 to 17 inches bore. Before the war a hundred rounds was considered the limit of the life of heavy naval guns, but since then the same guns have been found capable of effective work up to double and treble that number of shots. It is reported, however, that the new howitzers, which are of the built-up construction, are very durable.

When one of these big guns is fired the recoil is very heavy, the shell leaving the muzzle of the 12-inch Skoda mortar, for example, at 1,115 feet a second, and this recoil must be taken up by the carriage. To provide for this a deal of heavy mechanism is necessary in the form of brakes and the machinery for returning the gun to its firing position. This brake is usually of the liquid type, a piston attached to the barrel working in a cylinder forces liquid through a small opening, which can be regulated as desired, as the gun slides backward on its carriage. To return the gun compressed air is used, working in cylinders attached to the carriage in a way similar to the brakes. It is these brake and return cylinders that are seen grouped above and below the barrel of the guns in the many pictures that have been published.

In the descriptions of battles it is quite common to read of the "thunder" of the cannon, and while this term may

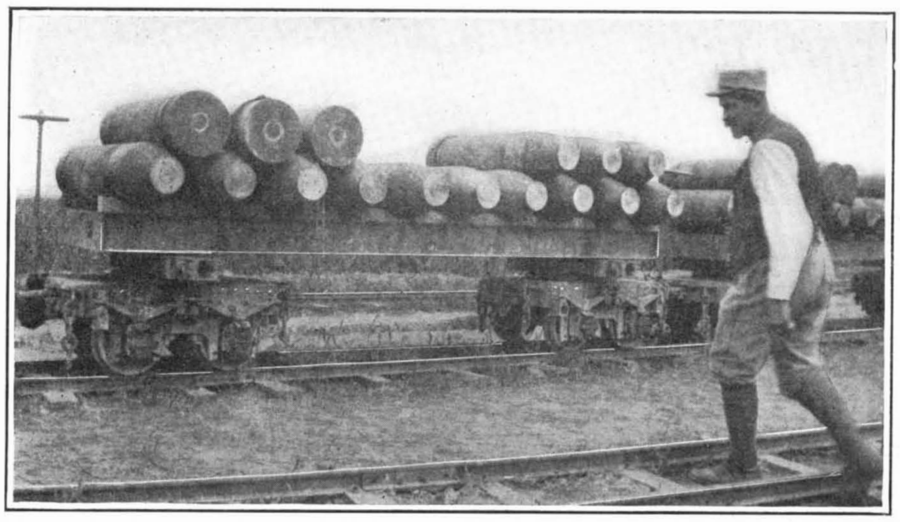


Photo by the Press Illustrating Service.

Special cars transporting big French shells to the front.

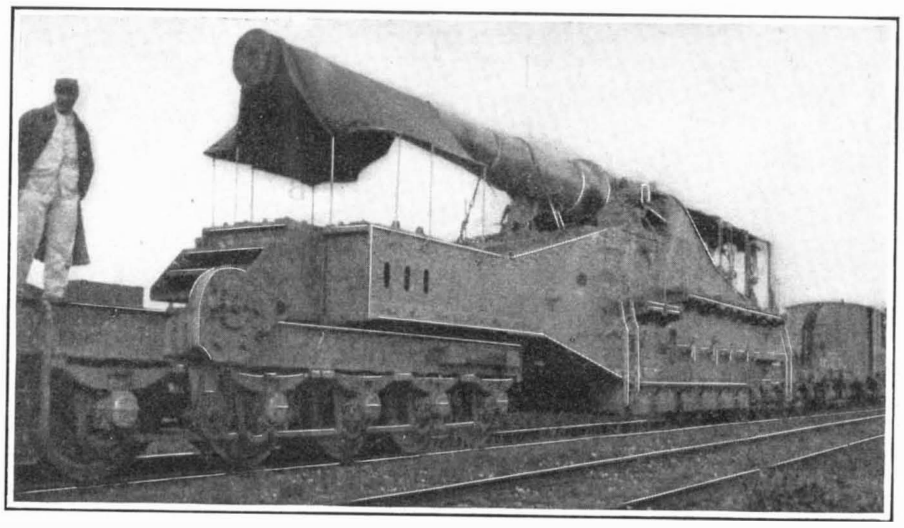


Photo by the Illustrating Service.

A long range French gun on special railway car.

have been more or less accurate in the old days of gunpowder it is no longer true at the present time, when both gun and shell are charged with the newer high explosives. In the modern battle we no longer hear the roll of thunder, but, as an English correspondent puts it, "a series of enormous strokes upon invisible anvils. The guns slammed sharply, with hard, metallic knocks." Such sharp, metallic knocks are characteristic of the detonation of modern high explosives, which take place in a very much shorter space of time than the old-fashioned black powder; and this sudden explosion, together with the greater power of the explosive subjects the gun to a strain that would destroy one of the old-time guns instantly. It is only because of the newer and stronger varieties of steel that are being used in building modern guns, together with improved processes and methods of construction, that it is possible to make use of the newer explosives in either guns or shells.

When one of these big guns has to be moved from one location to another the outfit is divided into several sections, usually three, each of which is hauled by a powerful motor truck of special construction. Thus the gun is transferred from its regular carriage, or firing mount, to a motor truck designed for the purpose, the carriage is taken by a second truck, while the foundation, which is often made in several parts for convenience in handling, is carried by a third truck. As these trucks cannot be limited in their operations to good roads, or even to roads at all, rubber tires are entirely discarded, and heavy metal-trimmed wheels are used, and these wheels are usually provided with an extra wide bearing surface by fitting to their circumference a series of steel-shod wooden blocks, each one being hinged to the wheel so as to maintain a flat bearing on the ground as the wheel revolves. Of late, however, railways have been utilized, both for bringing the guns to the front and for keeping them supplied with ammunition, light railway lines being laid directly to the point from which the guns are to be fired; and the guns frequently are mounted directly upon heavy, special cars that form a foundation platform from which they are fired directly. In other cases, as shown by one of the illustrations, the railway trucks have been designed merely for the convenient transportation of the gun, which is to be placed upon a specially prepared mount.

When the war started none of the Allies were provided with guns adapted for field service that could successfully cope with the heavy pieces brought forward by Germany and Austria, although in some places attempts were made to utilize long-range navy guns of large caliber; but preparations were promptly put into operation to supply the deficiency, and for some time reports have been coming of increasing numbers of large guns that are being operated, particularly on the western front; and it is due to the work of these heavy weapons of the Allies that they have been able to make the advances of the last two months. There is no definite information available as to the sizes of these new guns, but it is evident that they are sufficiently large to meet the German howitzers on equal grounds, and in some cases it is claimed the French guns are not only equal in size to the German's, but considerably superior in range and efficiency. A photograph of some French shells has been published which shows projectiles of 16.5, 14 and 12 inches diameter, with weights of 2,350 pounds, 1,400 pounds and 850 pounds, respectively, and from this it may be gathered what a wonderful effort has been made in the French gun shops that has resulted in a material number of such monster weapons in such a short time, together with ammunition to make them effective. England evidently has not been able to turn out as many nor as big guns as the French; still, they appear to be now provided with a large number of very effective weapons of considerable size, which seem capable of meeting anything the enemy has so far brought against them. Of the doing of Italy in gun-making, not much is known. At first she was as little prepared for war as the French or the English, but the results of her campaign would indicate that she has succeeded in making good her deficiencies; and from an illustration which we reproduce on the first page it is evident that Italy is not lacking in facilities for turning out as powerful weapons as employed by her opponent.

Imperial Trains of Europe*

By Walter S. Hiatt

Among other railroad material that is being worked overtime now because of the European war may be mentioned the palatial trains of the Emperors of Russia and Germany, the King of Italy, and that of the President of the French Republic. These trains have never been in service so frequently before.

Indeed, it is likely, should the war last many months longer, that the train of the President of the French Republic will have to be rebuilt. It is a war order that some enterprising American car builder may keep in mind. The train was about to be rebuilt when the war started, but the shorthanded conditions in the French car factories have not permitted the work to be carried out.

This train, while not the most luxurious and convenient of the official trains of Europe, has perhaps the most interesting history of them all. It has figured in more important political events than any of the others, and has carried at some time nearly all of the great men of the world, including, possibly, France's greatest enemy, the Emperor William himself. The train was hurriedly built in the autumn of 1896 for the immediate purpose of receiving the unexpected visit of the Czar of all the Russias, whose visit at this time cemented and put the official seal on the alliance between France and Russia, the most portentous political affair possibly in the whole history of modern Europe. The French wanted, as is their custom, to celebrate this visit themselves and to welcome their visitor with every possible honor. It was on this occasion, for example, that the trees of the Champs Elysees were decorated with hundreds of thousands of flowers, artificial flowers to be sure, owing to the lateness of the season, but yet flowers.

For the same reason the then most palatial of trains was built to carry the emperor from the frontier to Paris. Its four cars were built in 13 days at the order of President Felix Faure, and incidentally without the legal sanction that ordinarily must accompany such expenditures. This sanction was formally granted long after the emperor had gone home. So hastily was the private personal car of the four built that it was not recalled until the tenth day that the emperor might want to take a bath. So the roof of the car was promptly cut open and a space made large enough to permit the lowering of a huge bath tub into a corner of the car, not an ordinary bath tub, but one of solid silver. The tub is there after all these years, as is the patch in the car roof. I was at pains to note it when visiting the cars. This train has its own great special housing shed at Villeneuve St. Georges, some miles out of Paris, though it has been as frequently out as in that shed this year.

In October the train was used to convey the King of England to the French front where he reviewed in company with President Poincare 50,000 of the troops that had taken part in the victory of last September about Rheims, the victory to-day known as that of the fields of Champagne. Although the review took place but 12 miles behind the front, neither the King of England, nor the troops, nor the train was bombarded by the Germans, for the simple reason that the Germans did not know the place where the review was being held.

The train was used late in August for the purpose of conveying the King of Belgium to Paris. It was on this occasion that the king lost his suspenders, or rather, being used to a soldier's life and uniform, he forgot to put them on the morning he left the train after his night ride from Paris back to the northern front of the war.

The ceremonial train of the French Republic differs from the imperial trains in that it is not armored, and has no protection whatever against bullets and shells. It was built at a time when such trains had neither been conceived nor thought necessary. All of the four cars are elaborately upholstered in red and yellow silk velvets, and all are of wood construction, each 40 tons in weight. The cars are not at all of the typical French construction, but look rather like the massive American Pullman parlor car, except that the roofs are not fully rounded at the car ends. The interiors of the cars resemble somewhat the inspection or tourist cars used on the western railways of the United States, and have none of the abrupt divisions and cross compartments peculiar to the English or continental cars. While thoroughly comfortable, however, it is apparent by their fading curtains and upholstering, by their too palatial parlors, by their clumsy and ponderous arrangements which can no longer be called conveniences, that they have outlived their time and usefulness. They vaguely remind one of the old palace at Oiron, whose magnificence is falling into decay because no one can afford to live in the place.

In sharp contrast is the Imperial train of Germany which conveys the Emperor William to his several battle fronts. All of the seven cars of the train are partially armored, with bomb-proof bottoms and tops. When the train is run near the front it is pulled by one of the many armored locomotives now so common in France and Germany, a locomotive prepared to resist not only aeroplane bombs but cannon shell, a locomotive whose armor reaches down to the tracks and curves sharply upward until it closely resembles a land Merrimac.

A feature of the train is the library car in which is hung up a multitude of military maps, more than 700, for the study of the operations of German and enemy troops. Of course the train has its special telephone which can be connected at any station.

The special train of the Emperor of Russia is the most luxurious and longest of them all. It is composed of a dozen cars and is often run in two sections. It was adapted to war uses long ago, before the present conflict was thought of, its top, bottom, and sides being heavily armored and proof against dynamite charges planted on the tracks. Some of the cars are set aside for the emperor's suite and guard, in others provision is made for a real Russian bath, a real kitchen, a smoking saloon and every comfort that the emperor might find in one of his own great palaces. There is also a chapel installed for use in worship and various religious services.

Despite the many journeys now being made in these special trains, and the vigilance and effort of the enemy aeronauts, none so far has actually been injured during the war.

*Special European correspondence of the *Railway Age Gazette.*

Internal Combustion Engine Cycles—II*

Possibilities of the Constant Pressure Cycle

By Arthur B. Browne and Herbert Chase

Concluded from Scientific American Supplement No. 2123, Page 174, September 9, 1916

DESCRIPTION OF THE BURNER.

The operation of the proposed cycle is dependent to a large extent upon the functioning of the burner marked *17* in Fig. 2 and shown in detail in Fig. 3. To understand the operation of this burner it is necessary first to have clearly in mind certain fundamental laws governing flame propagation. Imagine a tube composed of material that is a non-conductor of heat, this tube being closed at one end and open to atmosphere at the other. Now suppose the tube be filled with a highly combustible mixture of air and gas. If the mixture be ignited near the open end of the tube the flame will travel toward the closed end at a rate of speed dependent chiefly on the quality, temperature and pressure of the mixture.

Suppose now a vessel containing a combustible mixture under pressure be connected to the open end of the tube. If the end of the tube formerly closed is then opened the combustible gas in the vessel will flow out through the tube at a rate dependent upon the pressure. If now the mixture be ignited at a point midway of the tube the flame will propagate itself either toward the vessel or away from it according to the relation between the velocity of the gas and the rate of flame propagation. If the rate of flame propagation be greater than the velocity of the gas through the tube the flame will travel against the flow of the gas and ultimately enter the vessel from which the mixture is issuing. If the velocity of the gas is greater than the rate of flame propagation the flame will travel with the flow of gas and ultimately blow out at or near the open end of the tube. If, however, the rate of flame propagation is equal to the velocity of the gas the flame cap will remain stationary, the combustible gas approaching it from one side and the products of combustion leaving on the other.

In the case of the burner shown in Fig. 3 the combustible mixture enters under pressure through the pipe *A* and fills the annulus (called the diffusion chamber) surrounding the combustion chamber *B*. Entrance to the latter is afforded by openings *C* so arranged that the streams of gas come from opposite directions and meet at a point where their velocity is zero. The velocity at the point of entrance to the combustion chamber of the burner will depend upon the pressure difference between the combustion chamber and the chamber from which the gas issues. Suppose now the pressure difference is such that the velocity at the point of entrance is one hundred feet a second and that the rate of flame propagation in the particular mixture under consideration is fifty feet a second. If the gas be ignited by spark plug *D* after entering the combustion chamber, the flame cap will travel against the gas current until it reaches a point where the velocity is the same as the rate of flame propagation, in this case, fifty feet a second.

Such a point must exist between the point where the velocity of the gases is zero and the point of entrance. Otherwise the flame will travel through the opening through which the gas is entering, and ignite the mixture approaching the burner. To confine the flame within the burner it is therefore necessary at all times to maintain at the point of entrance a velocity higher than that of the flame propagation. This will result in maintaining the flame within the burner and the products of combustion will issue from the outlet *E* of its combustion chamber.

In practical application of the burner already made it has been found that the burner can be operated over a wide range of pressure differences without adjustment and it has also been found possible to use the burner with the heaviest and cheapest grades of oil obtainable and still secure complete combustion, at least so far as the eye and nose can detect.

In case liquid fuel of low volatility is used it is of course necessary to heat the air in which the fuel is mixed and see that the latter is finely divided. In practice this is done as follows:

The air, passing through the atomizing device *25* (Fig. 2), becomes impregnated with fuel mist and is immediately conducted through tubes where its temperature is raised by contact with the hot walls of the inner tubes *11*, carrying exhaust gases. This exhaust heating at constant presure, not only effects the material increase in efficiency already noted, but serves to make a fixed gas of the mixture, which may thereafter be safely conducted to the point of combustion without fear of condensation. With gasoline this fixation is unnecessary. Hence a ready means for starting a cold engine is available.

In applying the burner to an engine it is necessary simply to see that the conditions outlined for properly mixing and volatilizing the fuel are met. If the temperature of the air passing the nozzle *10*, Fig. 2, is sufficiently high to cause immediate ignition of the fuel, two alternatives are open. The first is to maintain a velocity in the mixing chamber that is always greater than the rate of flame propagation in the mixture. The second is to make provision as by valves *23* and *24* (Fig. 2) whereby the mixture while on its way to the burner is too rich to ignite, that is, until sufficient air entering through auxiliary inlet *F* (Fig. 3) is added to this over-rich mixture in the space surrounding the combustion chamber so as to secure complete combustion.

The degree of rapidity at which the heat is liberated in the burner is indicated by the fact that it has been found possible in tests already made to melt a bar of steel inserted in a burner made of brass. The design of the burner is such that the gases entering insulate the walls so that the latter remain comparatively cool.

ADVANTAGES OF THE PROPOSED CYCLE AS APPLIED TO AUTOMOBILE ENGINES.

The advantages resulting from the use in a motor vehicle of an engine operated on the proposed cycle include all of the inherent advantages of the constant pressure cycle previously mentioned. While the field in which it may be applied is by no means limited to that of the motor vehicle this cycle is peculiarly adapted to motor-vehicle engines for the following reasons:

(1) It renders available for use fuels, such as kerosene and oil fuel, now produced in such large quantities (to supply the demand for gasoline) that they have become more or less of a drug on the market.

(2) It is thermally efficient at all loads because of the constant compression pressure, utilization of exhaust heat and other factors outlined under the heading "Advantages of the Constant Pressure Cycle."

(3) It produces a more uniform torque and is smoother in operation than any Otto cycle engine owing to the fact that fuel can be admitted through a considerable proportion of the stroke and that there is no sudden rise of pressure such as produces sudden and violent shocks in an engine operating on the Otto cycle. Under these conditions it is impossible to see any necessity for an engine of more than four cylinders, while it is probable one of fewer cylinders can readily be used.

(4) It has a considerable overload capacity. In other words the normal turning effort can be much increased either by increasing the pressure on the unloading valve and thus raising the compression pressure or by lengthening the admission period up to practically full stroke. Under these circumstances it is possible to dispense entirely with a change speed gear as is done in the case of steam-driven cars and locomotives.

(5) It can be operated on a two-stroke cycle and thus further decrease the variation in torque and the loss in power resulting from the two idle strokes in a four-stroke cycle engine. In short the engine will possess all the inherent advantages of the two-stroke as compared with the four-stroke cycle without any of the disadvantages of the former, which have operated against the success of a two-stroke Otto cycle engine.

(6) It can be built to produce much higher mean effective pressures than do engines operating on the Otto cycle. The engine therefore can be made much lighter for a given normal power than any Otto cycle engine practicable for motor-vehicle use. The design can also be made as compact as that of the motor-vehicle engines now used.

(7) It will probably require no starting device. When the engine is stopped after running for even a short period of time, air under pressure will remain in the receiver. Under these conditions it will be necessary only to open the throttle, permit the air remaining under pressure to flow into the mixing chamber and thus through the burner into the cylinder. If the clutch be held out during this starting period the air pressure even though it be low will under normal conditions be sufficient to start the engine. Once started the engine will in a few turns fill the receiver with air at the normal compression pressure of the cycle. In case an engine stops on dead center and all air in the receiver leaks out, the engine can be cranked by hand or a small hand pump used to fill the receiver.

(8) It will in all probability be comparatively free from difficulties due to the accumulation of carbon, providing a reasonably good grade of lubricating oil is employed, because of the ideal combustion conditions previously mentioned.

(9) It will operate to decrease car weight on account of its own light weight and the fact that no gear change or starter will be required. Owing to the smooth torque characteristics the whole driving mechanism can probably be made lighter than under present conditions. It is probable also that no muffler will be required on account of the expansion and cooling of the exhaust gases occurring in the regenerator. It should be entirely free from difficulties corresponding to those now resulting from imperfections in carbureter design and operation.

(10) Its use will result in a much simpler control of the car owing to the absence of any gear-changing mechanism. There is no occasion for a spark advance mechanism since the mixture will always be ignited the moment it enters the burner; hence pre-ignition is impossible.

(11) It will be as easily reversible as a steam engine, hence no reversing gear will be required.

CONCLUSION.

In view of the numerous advantages of the constant pressure cycle and the peculiar advantages of the proposed theory of construction the authors anticipate a rapid change from the constant volume to the constant pressure type of engine in automobile construction.

BIBLIOGRAPHY.

The authors have purposely avoided the use in this paper of formulas having to do with the thermodynamics of the constant pressure cycle, for the reason that this ground is covered thoroughly in most reference books on the gas engine.

Particular attention is called to the paper by R. M. Neilson, quoted at length in Suplee's book on "The Gas Turbine," in which the author states that with a compression pressure of only 30 pounds absolute (approximately 15-pound gage) a constant pressure engine has an *ideal* efficiency of 84 per cent, the highest ideal efficiency of any cycle mentioned, including the Otto cycle with an ideal efficiency of 40 to 45 per cent.

Another point worthy of special mention is that cited by Hiscox in his book entitled "Compressed Air and Its Applications." In the chapter devoted to "Compressed Air Reheating and Its Work" it is made evident that one of the most efficient methods of converting heat energy into useful work is to heat air already compressed and expand it in an air motor. Hiscox states that 1.28 horse-power can be developed by the combustion of one pound of coal per hour, or where the internal combustion method of heating is used (products of combustion are added to the air) no less than 2.4 horse-power per pound of coal per hour may be developed—a far better efficiency than can be realized in any known type of steam power plant.

The constant pressure engine can be considered practically as being an air motor in which the air is heated after being compressed and then allowed to expand in the same cylinder in which compression takes place. In the cycle proposed in the paper heating is done in a most efficient manner with slight opportunity for loss of heat energy, since the latter is not liberated until the air enters the cylinder in which the work is done. Furthermore, a considerable proportion of the heat normally lost in the exhaust is returned to the next charge of air entering the cylinder.

*A paper presented at the Semi-Annual Meeting of the Society of Automobile Engineers. Republished from the *Bulletin* of the Society.

The Truth About Colored Rubber*

How Color Is Obtained and Why It Is Unrelated to Quality

By Webster Norris

THE production of crude rubber and its manufacture into the myriad objects of daily use comprises a most important industry. It is so important that vast capital and a small army of agricultural, chemical and engineering experts and inventors are studying every phase of the subject in the effort to produce better goods and new applications.

Ordinary vulcanized rubber is so familiar as a black, white, gray or red elastic or resilient substance that it is quite natural for those who use it in any form, without manufacturing knowledge, to believe that its observed colors mean more than they do, and to associate the notion of quality with a non-essential-like color, or possibly odor.

It is very convenient for the purposes of the advertising man to claim color as a guide to quality in rubber goods and associate the two ideas as related whether they are or not, so long as the customer is directed to some trademarked line that may perchance stand for superior quality. There are other misconceptions about rubber, the currency of which are not in any way attributable to advertising zeal, as, for example, that rubber is melted and poured into molds to give desired form to any article.

Crude rubber is the dried gum from the latex or milk-like fluid derived from a variety of trees and vines native to the tropical countries of South and Central America, Africa and Asia.

The rubber industry began less than seventy-five years ago, and developed gradually for fifty years until about the period that rubber tires began to appear. Since that time the remarkable increase in the use of rubber has been more rapid than the production of the material from its wild sources. This condition led to the establishment of plantations for the cultivation of the best, or Para grade, first in Ceylon, under government aid, and later in Malaya and elsewhere. During the long experimental stage serious doubt was entertained as to the success of the rubber planting industry; today, however, the world derives over 66 per cent of its annual supply of rubber from the plantations of the Far East, and this proportion is steadily increasing.

Crude rubber, as received by the manufacturer from the wild sources, is in balls, blocks, rolls, strips or slabs, usually wet and very much mixed with earth, bark, leaves and wood. The plantation grades are uniformly in clean sheets or blocks, dry and free from foreign admixtures.

The preparatory processes of working are essentially the same whatever the quality of the crude rubber or the ultimate product of its manufacture. These processes begin with washing to remove the earth, wood, bark, etc., and there is a rough standard shrinkage by washing to which each well defined market grade of rubber may be expected to approximate. This loss varies from 5 to 50, or more, per cent by weight, according to the source of the rubber. There is an extremely wide range as regards strength and other properties of clean rubbers derived from various sources, which is taken into account when selecting for manufacture.

Formerly, after washing, the rough sheets of clean rubber were dried in a warm ventilated loft for weeks. The modern practice is to dry the sheets on trays in a vacuum steam oven, by which the water within the rubber substance is rapidly removed under reduced pressure without danger of injury by overheating. This important advance in rubber working is due chiefly to a gifted American engineer, Joseph P. Devine, of Buffalo, N. Y. Pure unmodified rubber is not suitable to many technical uses, but can be made so by proper mixing, or compounding and vulcanizing.

Vulcanization, or the union of sulphur with rubber, was Goodyear's great invention. It is the basic process in rubber manufacture. The term indicates the chemical changes producing the well-known characteristics observed in rubber goods, such as hardness, toughness, elasticity, etc. The variety of materials employed for admixture in rubber is very great, and the catalogue of such materials may be divided approximately into vulcanizing agents, tougheners, fillers without chemical influence, and pigments. This list of ingredients is so large that a practically limitless variety of rubber stocks is possible, giving to rubber its unique position in the modern world.

*From the *Horseless Age.*

It is evident that the production of a rubber stock of special quality requires the exercise of much experience and scientific knowledge. This work constitutes one phase of the rubber chemist's work, as he controls the factory routine processes. Rubber compounding is directed to secure some specific result with the materials employed, usually the production of goods to give creditable service under given conditions; sometimes, however, to meet a price proposition where disproportionate value is sought by the purchaser (who is uniformly disappointed, as a matter of course).

The numerous crude rubber sorts and the long list of compounding ingredients offer the chemist a wide range of resources wherewith to exercise his skill. Among the rubber grades are those, for example, that have crisp, strong fiber suitable for wear resisting, tough tire treads when rightly compounded and others which can never be made into equivalent stocks, whatever the compounding. Among the mixing ingredients some have chemical effect, others purely physical, and still others exert both of these functions. The principal vulcanizing material is sulphur. Its chemical effect changes the crude rubber into an essentially different material. The metallic oxides, sulphides and certain organic compounds assist the process of vulcanization and otherwise modify the physical properties, and some of them incidentally affect the color of the product.

The natural color of vulcanized rubber free of pigment is black for ebonite or hard rubber, and gray for soft cured rubber. Referring more particularly to heat-cured soft rubber goods, such, for example, as tires, hose, water bottles, bulbs, etc., these articles are made in black, white and red chiefly, although other colors are possible. The pigments are mineral colors, metallic oxides or sulphides mixed into the rubber by milling on iron rolls.

Organic colors are unstable in contact with heat and sulphur, and for this reason are limited as rubber colors to use in the cold cure process for transparent and surface effects. The trivial value of color in rubber is evident in the case of a tire tread or even a hot water bottle, where service is the real test of quality, and quality means good rubber scientifically compounded and carefully cured, whether colored incidentally or intentionally.

An excellent quality of tire tread or water bottle can be made either red or white. They can also be made of equal or superior quality in some other color. A red rubber article may be red because it contains antimony, oxide of iron or red reclaimed rubber and in each case the quality may be vastly different.

The pigments used in rubber have no beneficial effect on the rubber mixture, either preservative or otherwise, except in case of zinc oxide and antimony sulphide, particularly the former, which is remarkable as a toughener. They are both used mainly for this purpose; the zinc oxide to a greater extent than the antimony, because the white stock produced is cheaper and may be given any other color desired. Color as a feature in rubber compounding is thus seen to be a matter of taste or fancy and of value only in adding distinction to some trade design. A discriminating purchaser may thus be aided by it in identifying the goods sought.

No manufacturer is warranted in claiming to be the headquarters for red or any other color of rubber nor to base a claim of superior quality on the particular color he offers in his goods. The truth is that progressive manufacturers, both large and small, have long recognized the value and need of scientific investigation in the development and control of their products. Their chemists are continually studying to secure increased value in the goods. Differences in experience and skill naturally are reflected in the product, not only as regards quality and color, but in many other respects.

White color in rubber is obtained by zinc oxide, or lithopone, a preparation of zinc oxide and barium sulphate, sold under various trade names and largely used in rubber work.

Red color in rubber is obtained by crimson sulphuret of antimony or the cheaper and effective red oxides of iron in various grades.

Black, when especially sought, is obtained by the use of lampblack. The natural dark color of vulcanized rubber is often made practically black, as in the case of tires, by the incidental color of such material as refined asphaltum, known as mineral rubber. When lampblack is used, the amount required is small owing to its powerful covering quality as a pigment. The percentages of these colors required to produce the ordinary white, red and black rubber are about as follows: white, 30 to 40 per cent; red, 10 per cent; black, 2 per cent.

The prices of practically all of the compounding ingredients for rubber are on a war basis. Zinc oxide and lithopone have risen 200 to 300 per cent above normal; antimony red is scarcely to be had; lampblack has risen proportionately less, but is of small consequence, compared with zinc and antimony.

At a time like the present the tire manufacturer continues to make white treads by observing the strictest economy in his use of zinc and lithopone or wisely makes a better stock with something else, regardless of color. For red tires he abandons antimony and uses oxide of iron. In this way he may be very little inconvenienced by existing conditions in the matters of quality, price or color.

An average tire tread showing 45 per cent mineral besides sulphur, if white would show all zinc oxide or lithopone; if red, 10 per cent antimony sulphide or iron oxide and 35 per cent zinc oxide or lithopone; if black, it would contain a mixed assortment of materials about half with vulcanizing effect and half inert fillers

War conditions have affected the availability of many of the materals used in rubber manufacture, but this has served to stimulate closer study, and in tires, for example, has been maintained or even surpassed by newly applied resources

Regarding quality in automobile tires, the question frequently is asked, How much actual rubber is in an inner tube and a tire casing? The ordinary high grade tube contains about 90 per cent of Para rubber. The average tire casing contains not only several qualities of rubber composition, but these vary in grades of rubber employed, although Para, either wild or plantation, is the principal one.

Reclaimers of waste rubber find that the average composition of automobile casings is, approximately, fabric, 50 per cent; rubber, 25 per cent; mineral ingredients, 25 per cent. The rubber and compounding ingredients in a tire tread composition will probably average, rubber, 50 per cent; metallic oxides, inert fillers and pigments, 45 per cent; sulphur, 5 per cent.

Having realized the lack of reliability of surface characteristics as indications of quality in rubber goods, the purchaser may well inquire what course he is to pursue in selecting, for example, a tire. As between several tires, red, white, black, gray or any other color singly or in combination, makes no selection on color, weight or odor. If not familiar with tire construction simply select a manufacturer whose experts have solved the problem. By this course one's judgment is backed by a competent organization and any failures of the goods in service can be put up to the organization with confidence in the outcome.

News by Wireless

THE story of a correspondent who spent an evening in the wireless room of a British battleship stationed in the North Sea illustrates the great range of many present-day radio stations. On that particular evening, which he admits was unusually favorable to wireless communication, he heard Poldhu, the Welsh station of the Marconi chain; Nordeich, the German station from which the Teutonic version of the war is sent out daily to ships at sea; the Eiffel Tower station at Paris, which handles a goodly part of the French Government's orders to distant commands; the Spanish station at Madrid; the Russian naval commander in the Baltic as well as the Admiral of the British Grand Fleet, the German Commander-in-Chief with his land-locked fleet, and the British Commander-in-Chief in the Mediterranean. The correspondent comments on the ease with which the operator was able to tune in any desired station while eliminating the others.—*The English Mechanic.*

The Pallograph*

An Ingenious Instrument for Recording Vibrations

THE only pallograph in America, and, indeed, one of but two or three in existence, has lately been completed by the Sperry Gyroscope Company for the use of the United States Navy engineers at the Model Basin, Washington, D. C., in connection with their investigation of vibration of ships. Briefly, the pallograph is an instrument which simultaneously records vertical and horizontal transverse vibrations; and while the instrument is primarily intended for use aboard ships, it may be used to trace vibrations or oscillations of any character to their primal source. Doubtless the first practical pallograph was the one made some years ago by Dr. Schlick of Hamburg, and it was he who demonstrated the wonderful results that may be achieved by means of this device in definitely locating the source or cause of vibrations.

A pallograph consists of six principal parts, namely:

(*a*) Apparatus for measuring vertical vibrations.
(*b*) Apparatus for measuring horizontal vibrations.
(*c*) Mechanism for propelling the recording strip.
(*d*) Electrical connection with ship's tail-shafts.
(*e*) Clockwork for registering seconds; and
(*f*) Marking-pens.

When the pallograph is set up on a vessel where it is moved up and down by vertical vibrations, a weight, shown diagrammatically at *W*, in Fig. 1, by reason of its inertia remains at rest, although it appears to move rapidly up and down. When the apparatus is in a state of rest, a vertical impulse given to the weight will cause it to swing up and down with oscillations having a certain regular period. When measurements of vibrations are to be made, this period must always differ materially from the period of the vibrations which are to be analyzed; otherwise the weight would begin a synchronous oscillation, and anything like a record of vibration would be impossible. The period of the weight is quickly changed, however, by varying the tension of the spring *S* and moving it to or from the point marked *P*.

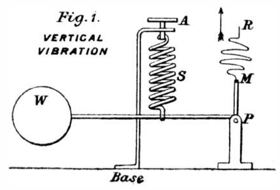
The pendulum used to record horizontal oscillations is diagrammatically illustrated in Fig. 2. It will be noted that the swiveled sleeve, *A*, is adjustable in a restrained vertical direction, and it will be readily understood how, by raising or lowering this sleeve, the pendulum may be lengthened or shortened—every slight adjustment of the sleeve is tremendously multiplied in its effect near the critical point—on the one hand representing a pendulum hung from a height of several hundred feet, and on the other almost zero height. Indeed, in the Sperry pallograph it is possible to arrange the parts so that the weight acts as if suspended from a practically infinite height, thus creating a pendulum of many miles in length, and the length of this pendulum may be adjusted from zero to maximum in two or three seconds.

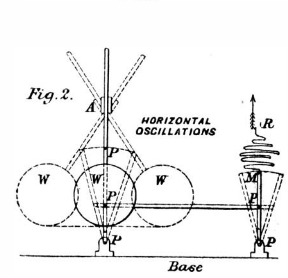
Records are made on a 5-inch paper strip, which is moved upwardly at constant speed by a small motor; the speed of travel may be regulated from 1½ inches down to ⅝ inch per second, as required. It will be readily understood that vibrations of high frequency or of considerable amplitude should be recorded on a rapidly moving strip, so that the wavy lines of the diagram may be widely separated for thorough analysis; indeed, it is even frequently necessary to enlarge certain sections, so that conclusions as to the cause of the vibrations may be determined with absolute certainty.

A collar being fitted to each propeller-shaft with an ordinary electrical connection, each revolution of each shaft is electrically transmitted to its respective recording-pen. The records shown in the illustration of the complete instrument, Fig. 3, reading from left to right, are as follows: Vertical vibration, horizontal vibration, tail-shaft, tail shaft and seconds. The instrument is shown equipped with pens for recording the revolutions of only two propeller-shafts, but it is understood, of course, that provisions have been made for the attachment of as many pens as there are tail-shafts in the ship on which the tests are conducted.

In discussing the analysis of the diagrams produced by the pallograph, Dr. Schlick stated: "It is necessary, in the first place, to exactly determine the period within which the ordinates always have the same value. When the curve is a regular one, the determination of the period is a simple matter. If, for instance, the curve *C C C* in Fig. 4 be given, tangents *a a* and *b b* are drawn to its succesive uppermost and lowermost points, so that these are respectively connected with one another. Then a line *c c* is drawn in a position about midway between *a a* and *b b*, as may appear suitable, parallel to these, cutting the curve *C C C* in the points m, n, m_1, n_1, m_2, n_2, etc. The distances apart of the analogous points of intersection m and m_1, m_1 and m_2 or n and n_1 then correspond with the period.

"The curves, however, which occur in the pallographic investigation do not show the complete regularity here assumed, at any rate in the case of steamers with two or more screws, for, in the first place, the speed of advance of the recording strip is not absolutely uniform, and in the second the period relations borne by the vibrations of higher order to those of lower order are constantly changing. Both these circumstances tend





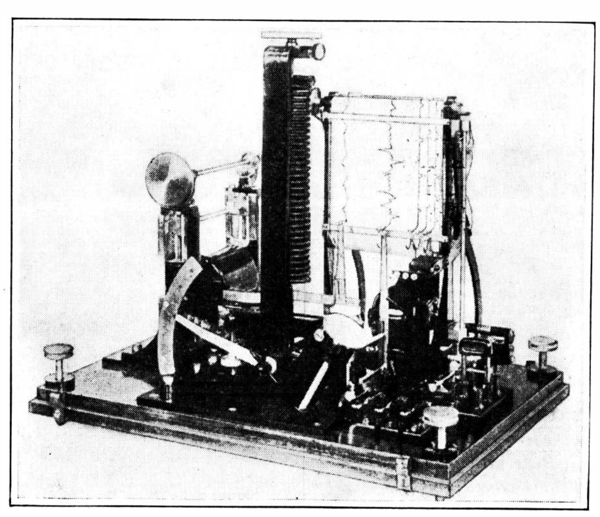
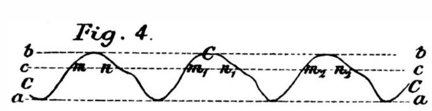
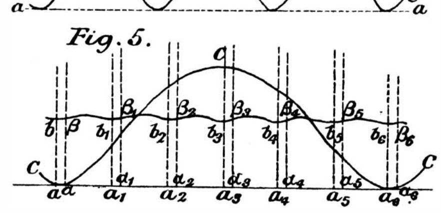


Fig. 3.





to make each successive wave differ in form from its predecessor.

"In the application of the pallographic curves the only practicable method of determining the period is first to endeavor, in the manner above described, to fix the length of the waves. In this more or less considerable differences will present themselves, which, however, will preserve a certain regularity in so far as they will keep on gradually increasing or decreasing in one particular direction. The investigator must then follow his instinct in finding two points on the wave-line that are a wave-length apart. After a little practice this may be done without considerable error.

"After, then, the wave-length has been found from a curve by the determination of the points a, a_6 (see Fig. 5), the analysis may be proceeded with in the following manner: The investigator must first make up his mind how far he will carry his analysis—i. e., up to what order of curve. It may, for instance, be proposed to investigate the curves up to that of the sixth order.

"The distance $a\ a_6$ is then divided into six parts, and ordinates are set up at the stations a_1, a_2, a_3, a_4, and a_5, so as to cut the curve. The arithmetic mean of these ordinates is then determined and the distance is set off at each of the stations, so that the points b_1, b_2, b_3, . . . are obtained. These points then belong to the curve of the sixth order. After this, further ordinates are set off at the stations a, a_1, a_2, . . . a_6, which are moved along through equal distances, $a\ a = a_1\ a_1 = a_2\ a_2$, etc., to the right of the stations first set off. The length of these distances $a\ a$. $a_1\ a_1$, etc., is of no weight. The arithmetic mean of all the ordinates set up at the new points of the curve *C C C* must here again be determined and set up from the base line of the new ordinates. The points thus set off, β, β_1, β_2, . . . β_6, belong to the desired curve of the sixth order also. Hereupon a fresh group of ordinates is taken in hand, and additional points on the curve of the sixth order are found in the same manner as before. In this manner it is possible to determine any desired number of points on the curve required.

"When the curve of the sixth order has thus been found, its ordinates must be subtracted from those of the original curve *C C C*, and a new curve is thus obtained, which may be called $C_5\ C_5\ C_5$. Should the curve of the sixth order, as will usually be the case, show waves of comparatively small height, the form of the newly found curve $C_5\ C_5\ C_5$ will not differ materially from that of the original curve *C C C*. The new curve $C_5\ C_5\ C_5$ now contains all the curves of the lower order, those of the sixth and of any higher order being eliminated.

"To determine the other curves of lower order, the curve $C_5\ C_5\ C_5$ obtained by the above process of subtraction must be treated in exactly the manner described for the curve *C C C*. The wave-length must be divided into five equal parts, and ordinates are then to be set up at the points of division, the arithmetic mean of which must again be sought. A line may now be drawn, in the same manner as before, which constitutes a curve of the fifth order.

"The ordinates of the curve of the fifth order are next subtracted from those of the curve $C_5\ C_5\ C_5$, and the differences set off again in the form of a new lower curve $C_4\ C_4\ C_4$, which then contains all the curves of lower order, those of the fifth, sixth, and higher order being eliminated.

"The curves of the fourth, third, and second order may now successively be found by similar application of the above process. After elimination of these latter, the remaining curve will be one of the first order, and must take the form of a true curve of sines. Errors of greater or less magnitude, due to unavoidable inexactness in drawing, will here, of course, show themselves.

"In vessels with three-bladed screw-propellers it will generally be sufficient to determine the curves of, and below, the third order, and in vessels with four-bladed propellers that of the fourth order in addition, since under such conditions the curves generally show vibrations of very small extent. Only in exceptional cases do curves of the sixth order show themselves in vessels with three-bladed, and curves of the eighth order in those with four-bladed propellers. Further curves of the fifth order never show themselves in connection with the former, nor curves of the seventh order in connection with the latter vessels.

"No curves of the fourth order occur in vessels having engines with three cranks and three-bladed propellers, and no curves of the third order in those having engines with four cranks and four-bladed propellers. It is, in fact, unnecessary to go to the trouble of seeking such curves."

**Engineering.*

Modern Methods in Surveying

IN spite of the systematic ageing of measuring wires by shocks, annealing, etc., experience has shown that restandardization is necessary both before and after each base measurement. In recognition of this the Indian Government has made careful preparations in undertaking extensive new triangulations. Invar tapes and wires 24 meters long are used, and these are regularly compared with invar bars. These bars are 4 meters long, so a comparator of 24 meters divided into six sections is required. A separate comparator 4 meters long is provided to compare the 4 meter bars with a 1 meter bar, which is compared with the primary standard. This 4 meter comparator is used both for comparisons of length and also for determining the coefficient of expansion, the latter process being done under water.

Unstable States in Arc and Glow*

The Diverse Ways in Which the Instability Asserts Itself

By W. G. Cady

In solid and liquid conductors, in which Ohm's law is applicable, unstable states, where a small variation in voltage produces a large change in current, are almost unknown. Exceptions occur only when a critical state in the conductor is reached, as, for example, in an iron wire at a certain temperature, or in an aluminium valve cell at break-down voltage.

Characteristics of the Gas Discharge.—When an electric current passes through a gas, the number of available carriers of the discharge increases with increasing current at a very rapid rate. In a popular sense, an ionized gas is a most "unstable" conductor, having a resistance by no means amenable to Ohm's law. In the language of dynamics, however, a gas discharge is normally stable in the sense that there is a restoring force to damp out small disturbances. The nature of this force, as well as the criterion for stability of any discharge, can be understood best by reference to the characteristic curve of the discharge shown in the diagram.

This curve shows qualitatively the relation between current and voltage in the discharge between two fixed electrodes. The nature and pressure of the surrounding gas are supposed constant, except as modified by conditions at the electrodes themselves. All of the common types of discharge are represented on this diagram. With a sufficiently high electromotive force it is theoretically possible, by decreasing the external resistance, to pass through all the stages in succession. Practically certain portions are unattainable, and different sources of supply are necessary for different forms of discharge. In any case, however, the curve is characteristic of the discharge apparatus and not of the supply.

The first part of the curve, OA, represents the saturation current, which soon assumes a value that is practically constant over a great range of voltage. This current is carried by the few free ions that are always present. As the voltage increases, the charged particles are sufficiently accelerated to form new ions by impact. At this point the current begins to increase, and a faint glow appears. The point A represents the sparking potential. In the present case the external resistance is supposed to be too high to admit of sparking.

AB is the glow discharge proper, in which the rate of ionization is so great that the voltage across the gap begins to drop. If the cathode is small, the curve may rise again before B is reached, owing to the abnormally high cathode drop.

Since the drop at the cathode is much larger than that at the anode, the cathode becomes relatively hot. As B is approached, the expenditure of energy at the cathode becomes so high that the cathode rapidly becomes incandescent. Here a new phenomenon appears, namely, the emission of electrons from the hot cathode, according to Richardson's law. These greatly increase the ionization close to the cathode, and the positive ions thus produced heat the cathode by impact still more. If the cathode metal is volatile enough, it begins to vaporize, thus lowering the cathode drop as well as the resistance of the gas.

The discharge quickly resolves itself into an arc, in which the negative base is concentrated to an intensely bright spot, the current is carried chiefly by the vapor from the cathode, but in which the mechanism of the discharge is essentially as before. The portion BC of the curve cannot be observed. Over CD the discharge is an arc as far as the cathode is concerned, but since less energy is being expended at the anode, at the latter we may still have a glow discharge. The positive base of the discharge is still diffuse and faintly luminous. This is the *first stage* of the arc.

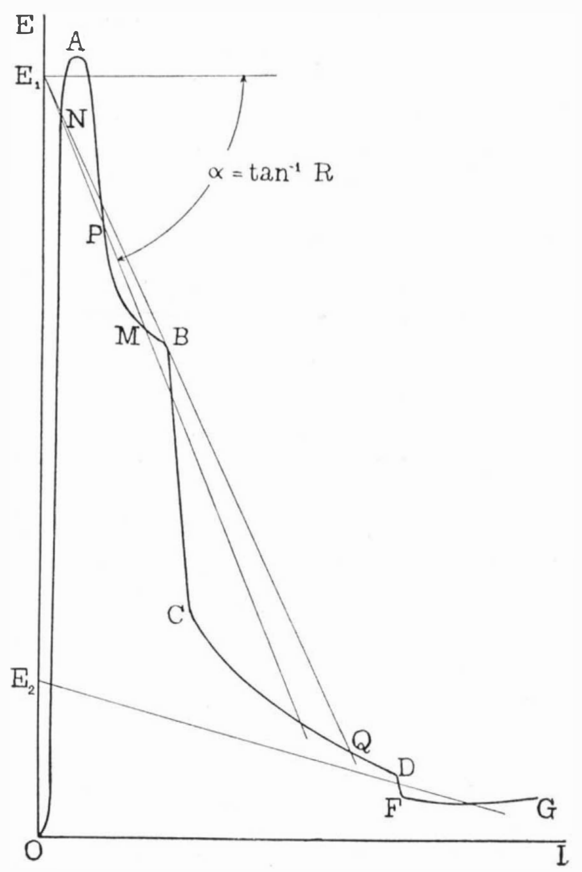
With increasing current the anode is brought to the boiling point. This causes a decrease in the anode drop and a further increase in conductivity of the gas, so that the portion DF is quickly passed over. FG is then a full arc, or *second stage* arc. Exceptions to this typical sequence of events will be described below.

Quantitatively, it is impossible to make the diagram give a correct idea of the voltage and current relations, since the current at G is in reality many thousands of times greater than at A.

Stability of the Discharge.—While theoretically it is possible to maintain a steady discharge at any point of the entire curve, practically the transition from one portion to the next is always discontinuous. As the voltage or the external resistance is varied, a critical point is always reached where the discharge is absolutely unstable, changing abruptly to a stable region on another part of the curve. Still, with any given supply electromotive force and external resistance, it is always possible to predict between which two points the discharge must change. The method of procedure is largely due to Kaufmann.[1]

Let us suppose that the supply electromotive force is measured by OE_1 in the figure. If M is the point on the curve at which the discharge takes place, then since the ordinate of M is the voltage consumed by the discharge, it is evident that the external resistance R is equal to tan α. If R is decreased, α must decrease and M will move to the right along the curve.

Kaufmann showed analytically that a stable discharge is only possible when the line through E_1, or the "resistance line" as it is called, *slopes more steeply than the characteristic curve* at the point in question. Thus, the discharge is stable at M, and, starting with zero current, it would also be stable at N with the same external resistance, but not at P. A glow at P could only be obtained with an enormously high electromotive force. At B the discharge is unstable; this is the first of the unstable states to which attention is directed. As soon as the point of tangency is reached, the discharge changes abruptly to a first-stage arc at Q. If now the external resistance is increased, the discharge does not change back to a glow along QB, but owing to the vaporization of the cathode it remains an arc until the point of tangency at C is reached. Then if, as is usually the case, the discharge cannot change to a stable glow, it goes out.



Characteristic Curves of Gas Discharge

OA, Saturation current; *AB*, Glow; *CD*, Arc, first stage; *FG*, Arc, second stage.

Similar points of instability exist at D and F. If the supply electromotive force is low, as at E_2, not even the first stage of the arc is possible, but only the second. This is the case with most arcs, operating with low electromotive force and small external resistance, and lighted by touching the electrodes together.

The physical significance of Kaufmann's criterion may be seen from the following considerations: If the resistance line slopes more steeply than the characteristic curve, then if through any chance the discharge at a given instant happens to take place at an abnormally high current, it cannot persist at this current, since the voltage available for the discharge is limited by the external resistance, and the steep slope of the resistance line brings the operating point too low for the discharge to be maintained; hence, the current settles back to its normal value. Similar reasoning will show that if the resistance line slopes less steeply than the characteristic curve, then any slight disturbance will grow until the discharge goes out or becomes stable at another part of the curve.

In a general way this sort of stability is, of course, analogous to the mechanical stability of a pyramid, which is stable or unstable according to whether it stands on its base or is balanced on its point. A more exact analogy would be furnished by a hydraulic model, in which the discharge tube was represented by a valve so contrived as to open wider, the greater the flow of water through it. This would provide the "falling characteristic." If then the water were supplied from a vessel of variable height, and regulated by a valve at the supply, it is evident that at high pressure and with the supply valve nearly closed, any given flow of water would be maintained more stably than if the pressure were low and the supply valve wide open, for in the latter case a much greater percentage of the total "resistance" would be in the valve of "falling characteristic."

Kaufmann applied his criterion of stability with great success not only to glow and arc, but to the point discharge, to a discharge gap ionized by an external source and, most remarkable of all, to the case of a discharge having a capacity in parallel with it. This came pretty near being the discovery of the singing arc, which, by a coincidence, was discovered experimentally by Duddell in the same year.

The Carbon Arc.—I have obtained a glow discharge and both stages of the arc between carbon terminals, using an electromotive force of 460 volts, in nitrogen at reduced pressure. Air was then admitted and the current increased until the hissing state was also reached, making four forms of discharge with the same electrodes. On the characteristic curve for carbon electrodes the hissing point would be represented by a kink similar to that shown at DF, but situated between F and G. The laws governing the current-voltage relations on transition between normal and hissing carbon arcs are the same as those discussed above.

First and Second Stages of Arc. Effect of Impurities.—The unstable state occurring between the first and second stages of the arc has been investigated by Arnold and the writer. It is on the first stage that the ordinary mercury arc burns, having an anode of iron or graphite. The change from first to second stage has now been observed with anodes of a large number of metals, though in some cases reduced gas pressure or exclusion of oxygen was necessary.

An instability in the discharge is sometimes occasioned by traces of impurities on the surfaces of the electrodes. It is well known that the glow tends to change to an arc more readily if the metallic cathode is contaminated with traces of oxide. This is related, of course, to the emission of electrons from hot oxides. At the anode in a glow or a first stage arc, traces of impurities serve as nuclei around which the discharge tends to become concentrated, though it is still a glow. This effect may become so pronounced as to be taken for a new type of discharge,[2] especially, since the voltage suffers a sudden drop when the concentration sets in.

An Unusual Type of Arc.—A very unusual type of discharge is that in which, as the current increases, an arc appears at the anode while there is still a glow at the cathode. Those who define the arc as essentially a cathode phenomenon will not be disposed to admit that this is an arc at all, yet it has every characteriistc of an arc at the anode, and the appearance here does not alter further when the arc phase sets in at the cathode. The writer has encountered this form of discharge with anodes of C, Ag, Cu and Hg, the cathode in most cases being of silver. The condition is decidedly unstable.

Is an Arc Possible from a Pure Metal?—The writer observed some years ago that a cathode of pure silver may become heated by the glow discharge in nitrogen nearly to the boiling point without the formation of an arc. At currents as high as 1.3 amperes the discharge is still a glow, though the molten metal is white hot and vaporizes so intensely that clouds of silver "steam" fill the discharge tube. This is important evidence that incandescence and vaporization of the cathode are not enough of themselves to cause the formation of an arc. Whether even at the boiling point of silver the glow would still persist if no impurities were present cannot be stated. In the present tests, at the highest currents, the cathode mantle always grew so large as to encroach upon the fringe of impurities that inevitably surrounded the

*A paper read before the New York Section of the American Electrochemical Society in joint session with the Illuminating Engineering Society as reported in the *Metallurgical and Chemical Engineer.*

[1] Kaufmann, Annalen d. Phys. 2, p. 158, 1900.

[2] Aagenbach, Phys. Zeitschr. 12, p. 1015, 1911.

molten mass, and then an arc immediately formed. The admission of a small quantity of oxygen also precipitated an arc.

Intermittent Dischrge. Corona.—Both glow and metallic arc, as well as the discharge from points, are sometimes found to be intermittent. For this to be the case, the current must be relatively small and the capacity of the external circuit considerable. There is usually a certain critical external resistance at which the intermittence vanishes, as shown by the cessation of sound in a telephone connected to the circuit. The phenomenon is closely related to the use of the arc as a generator of electric oscillations. The Cooper-Hewitt mercury interrupter is a notable example of intermittent arc.

In a strong magnetic field an arc can also be made intermittent. In this case the instability is due to the lengthening of the column of vapor by the magnet, causing the voltage to rise above the point where the discharge can be maintained. Owing to the incandescence of the cathode, the discharge quickly relights and the operation repeats itself.

The corona discharge from high voltage transmission lines is similar to a glow discharge, and is said to be often intermittent. It exhibits the characteristic cathode and anode phenomena, as well as the tendency to concentrate at certain points which were mentioned above. Since the air serves as one electrode, the corona has in some respects more in common with the discharge from points than with the typical glow.

Rotation at the Anode.—Two effects will now be described, illustrating the instability of gas discharges as certain currents. The first of these has to do with the anode, the second with the cathode.

In the iron arc in free air the discharge normally takes place between globules of molten oxide. The second stage sets in at a little over an ampere. A close examination shows that the bright spot at the positive end of the arc is in rapid rotation, describing a minute ring. As the current increases, this form of rotation suddenly changes to one in which the ring is still smaller, then at about 1.8 amperes a large ring takes its place, which presently yields the stage to a smaller ring again.

Each of the four types of rotation has its characteristic diameter and speed, and produces a faint note of a certain pitch. Oscillograph records show that the current and voltage undergo corresponding changes. Reasons have been given elsewhere[3] for believing that these movements are due to a reduction of the oxide at the positive base of the discharge, causing the base to wander to regions richer in oxygen. The changes from one type to the next are probably due to modifications in the composition of the oxide, brought about by increasing temperature. I have found similar effects to a slight extent in nickel and cobalt. These results have a bearing on the use of the iron arc as a wave-length standard in spectroscopy.

[3]Phys. Rev. 2, p. 249, 1913.

Glow-arc Oscillations.—The effect at the cathode to which reference has been made is of the nature of a rapid pulsation back and forth between glow and arc. To obtain it, the supply electromotive force must be high, and the gas should be hydrogen at atmospheric pressure, mixed with a little hydrocarbon vapor. The electrodes may be of any metal, placed very close together, the discharge current being of the order of 1/10 ampere.

When the discharge is a glow, a spot on the cathode becomes heated to such a degree that a small arc forms, but the voltage then drops so much and the current increases so little, owing to the shape of the characteristic curve, that the energy is too slight to maintain the arc, and immediately the glow sets in again. Such pulsations between arc and glow are of a frequency anywhere between 1 and 250,000, depending on various conditions. I have succeeded in converting 66 per cent of the power applied to the discharge into high frequency oscillations of this type. Unfortunately, the nature of the discharge is such that the conversion of large amounts of power by this means is impossible.

In these experiments no capacity was connected in parallel to the discharge, though the adjacent parts of the circuit acted as capacities for the high frequency currents.

The Singing Arc.—In the singing arc, including the Poulsen arc used in radio-telegraphy, a capacity and self-inductance in series are placed in parallel with the arc. The effect of the capacity is to drain energy from the arc when the current in the condenser circuit is in one direction, and to strengthen the arc current when in the other direction. Continuous oscillations are thus maintained, the condenser circuit receiving energy and timing its own impulses in a manner analogous to the balance wheel or pendulum of a clock.

The point of chief interest here is that, as Kaufmann, Simon and others have shown, such oscillations are possible only when the arc (or glow) possesses a falling characteristic. Simon has found that the alternating-current, or "dynamic," characteristic differs from the direct-current, or "static," characteristic, the difference being due to a sort of hysteresis, and that the result of this is that at high frequency the dynamic characteristic tends to change from a falling to a rising type. This limits the attainable frequency, but by reducing the hysteresis and choosing such conditions as will make the characteristic fall as steeply as possible, frequencies of over a million are easily reached.

If the oscillations are weak, the direct current through the arc simply fluctuates. This can occur with the carbon arc. If the oscillations are stronger, they put the arc out at each cycle, and before the arc relights the condenser becomes charged. The oscillating arc used in radio-telegraphy is of this type. A third type, in which the oscillations are powerful enough to make the arc relight in the opposite direction, produce a coarse tone and are not much used.

Effect of Second Harmonic.—When the oscillations are of the second type, extinguishing the arc at each cycle, the wave form is very complex. The second harmonic is especially prominent. As an example of oscillations of this type of audible frequency, the following experiment may be described.

A carbon arc is made to sing by connecting a large capacity and a self-inductance coil of low resistance in parallel with it. A second coil is connected to a capacity such that the natural period of the secondary circuit is nearly the same as that of the circuit connected to the arc. When the two coils are brought near together, the pitch of the arc changes, owing to the effect of close coupling. If the pitch falls, it can be made to reach an unstable value from which it suddenly jumps up a whole octave, the discharge remaining stable at this higher pitch.

The explanation of this is, that when any two oscillating circuits are closely coupled there are two possible frequencies, one higher and one lower, in either of which oscillations may take place. At a certain stage of coupling the higher frequency is just an octave above the lower. If now the arc is on the lower frequency and has a very strong second harmonic, then if resonance is also possible at the octave above, the harmonic may be reinforced to such an extent as to assume the role of fundamental frequency itself. The pitch then rises to the higher octave.

It is hoped that the phenomena that have been described may serve to illustrate the unstable nature of some form of gas discharge, as well as the very diverse ways in which the instability asserts itself.

With respect to practical conclusions, the following may be said: for stability, an arc should be operated with supply electromotive force, external resistance, and current all large. Or, if the discharge is to be a glow, a region on the characteristic should be chosen at a safe distance from a critical point, having due regard to the supply electromotive force. For oscillations, a steeply falling characteristic, small current, large electromotive force and artificial cooling of the electrodes are factors.

The History of the Safety Lamp*

The Result of One Hundred Years of Effort

By Prof. F. W. Hardwick, M.A., and Prof. L. T. O'Shea, M.Sc.

The earliest references to the nature of fire-damp appear to occur in the latter part of the seventeenth century. From these it is evident that the risk of its ignition and explosion were known, and it was recognized that ventilation (to keep the air very "quick") was a means of prevention of these dangers. The recognition of the presence of fire-damp by means of the candle-flame was also known. No remedy other than ventilation appears to have been suggested until about 1730 or 1750, when the flint-and-steel mill was invented. The invention is attributed to Mr. Carlisle Spedding of Whitehaven. The use of flint and steel in the presence of fire-damp is mentioned by Sir James Lowther in 1733, and Mr. John Buddle in 1813 gave a full description of the flint-and-steel mill. This instrument, however, did not give immunity from explosion. An explosion at Wallsend in 1785 was stated by Mr. Buddle to have been traced to the use of the steel mill, and he also affirmed that, although he had witnessed an explosion from the sparks emitted by the instrument, yet "the inflammable air has frequently fired at the sparks of the steel mills, but only when they are played near the place where the hydrogen gas is discharged." Matthias Dunn also asserted that explosions were originated by the flint-and-steel mill. Other attempts to avoid the use of naked lights in presence of fire-damp were made, and Von Humboldt describes a lamp invented by him in which a candle would burn supplied with air from an air-reservoir. The use of phosphoric lights, fish in a state of incipient putrescence, Amadou (or fungus tinder), and other schemes were suggested, while sunlight was directed down the shaft by mirrors, and proposals were made at a later date to reflect the light into the workings.

*Abstract of a paper read before the Institution of Mining Engineers, June 8th, 1916. From the *Chemical News.*

Some progress was also made in respect of the knowledge of the properties and composition of fire-damp. Some investigators recognized its similarity to hydrogen gas, and were aware that it was heavier than hydrogen, but lighter than air, and although Volta pointed out the differences between fire-damp and hydrogen as early as 1776, and Berthollet proved that it contained both carbon and hydrogen in its composition, still fire-damp continued to be spoken of as "hydrogen." In 1805 Dr. William Henry distinguished between marsh-gas and olefiant gas. The occurrence of fire-damp in coal-mines was, however, not understood at this date, and in many instances its presence was attributed to the decomposition of water by iron pyrites, or to the decomposition of water by the coal with separation of the hydrogen.

The years 1812 and 1813 were important in the history of the safety-lamp. On May 25th, 1812, an explosion occurred at the Felling Colliery. In consequence of this explosion, the Rev. John Hodgson, the incumbent of Jarrow and Heworth, and Mr. James John Wilkinson took steps which eventually resulted in the formation on October 1st, 1813, of the "Society in Sunderland for Preventing Accidents in Coal-mines." This society had, as patron, His Grace the Duke of Northumberland, there were sixteen vice-presidents, with Sir Ralph Milbanke, Bart., as president, and Mr. W. Burn as secretary. In addition, there was a permanent committee of twenty-eight, among whom were the Rev. Robert Gray, the Rev. John Hodgson, William Reid Clanny, James John Wilkinson, John Buddle, and Matthias Dunn. This society was most assiduous in its endeavors to promote the objects for which it was formed, and it was due to its efforts that the safety-lamp was introduced at this period. Among those who, at the time when the society was formed, were actively engaged in endeavoring to discover some safe means of lighting coal-mines were William Reid Clanny and George Stephenson, and the society, apparently influenced by Mr. Buddle's expressed opinion that nothing further could be done to prevent explosion by the application of mechanical agencies, that the only remedy lay in the discovery of some chemical method for rendering fire-damp harmless, as it was discharged, and that it had to look to scientific men for assistance in providing "a cheap and effectual remedy," eventually determined to apply to Sir Humphry Davy for assistance.

The work accomplished by the society in connection with the movement of the safety-lamp entitled it to be gratefully remembered by all interested in coal-mining.

Dr. Clanny.—William Reid Clanny was born in 1776 at Bangor, County Down, Ireland. He entered the medical profession, and eventually settled down in practice at Bishop Wearmouth, near Sunderland. In 1810 his attention was drawn to the subject of explosion of fire-damp in collieries. He invented a number of lamps, among which is the well-known Clanny lamp. On May 23rd, 1813, he contributed a paper on his newly-invented lamp to the Royal Society.

Clanny's first lamp (the "Blast" lamp) consisted of a lantern with cisterns of water above and below the light. Air was forced in by means of a bellows, so that it bubbled through the water in the lower cistern while the products of combustion escaped through a chimney at the top, the open end of which was narrowed and bent over so as to

dip beneath the surface of the water in the upper cistern. This lamp was tested on the surface on October 16th, 1815, and underground on November 20th, 1815. The construction of the lamp was subsequently modified; the water cisterns were abandoned, the oil in the oil-vessel was used to seal the inlet of the air, and the outlet consisted of a vertical chimney that tapered to a fine point.

His second lamp was exhibited to the Sunderland Society in December, 1816, was described before the Royal Society of Arts on April 2nd, 1817, and was known as the "Steam" lamp. Air passed in through a tube in the bottom of a lamp, and was conducted through an extension of the tube to a point high up in the lamp. Above the oil-vessel and flame, and situated about the middle of the lamp, was a water reservoir. The water in the reservoir was boiled by the heat from the oil-flame. The air was conducted below the oil-vessel by two tubes, and then passed up the sides of the cistern, where it mixed with steam from the boiling water, and finally escaped through the chimney.

A third lamp was the "Gaslight" lamp, which was stated to have been designed to burn fire-damp in lieu of oil in an atmosphere charged with gas. It was similar in construction to the steam lamp.

These early examples of Clanny's lamps show the important part that Clanny took in his attempt to reduce the dangers arising from the use of naked lights, and in 1843 the South Shields Committee for Investigating the Causes of Accidents in Coal Mines expressed their opinion of the value of his labors as follows:

"Dr. Clanny, in this country, appears to have been the first man of science that conceived it possible to enter into a contest with this destructive element (fire-damp), and, sustained by his unwearied philanthropy, has never ceased for thirty years to devote his talents and exertions to mitigate the horrors consequent upon its explosion. A life so spent, it is to be hoped, will not be allowed to pass without some mark of respect from his country, or of gratitude from those he has labored so much to benefit."

George Stephenson.—George Stephenson, born on June 9th, 1781, at Wylam, near Newcastle-upon-Tyne, was, at the age of fourteen, appointed assistant fireman at Dewley Burn Colliery, and enginewright at Killingworth Colliery in 1812.

The idea of his first lamp (the "Tube and Slider" lamp) was conceived from experiments made on blowers that he met with in Killingworth Pit. He found that the "Burnt Air" from five or six candles held to windward of an ignited blower would extinguish the flame. Further, that when fire-damp was ignited, an appreciable time was necessary for the flame to travel from one point to another, and his idea was that if the upper part of a lamp could be charged with burnt air, while the fire-damp was admitted below in small quantity and burnt as it came in, then the burnt air would prevent the explosion from traveling upward, and the velocity of the entering current would prevent it from passing downward. In the "Tube and Slider" lamp air was admitted through a tube one half inch in diameter, and passed from the center of the bottom of the lamp to the center of the wick; the bottom of the tube could be wholly or partly closed by a valve or shutter, and so the admission of air regulated. This lamp was tested on October 1st, 1815, at Killingworth Colliery. Subsequently, Stephenson undertook some experiments on fire-damp and tubes, which decided him to substitute three tubes for the single air inlet-tube, and he constructed his second, or "Tube" lamp, in which the air was admitted through three tubes 3½ inches long and 3/22 inch in diameter; the air passed from the bottom of the lamp through the oil-vessel, the upper ends of the tubes being inclined toward the wick. This lamp was tried at Killingworth Colliery on November 4th, 1815. Subsequently, Stephenson decided that to admit air into the lamp through capillary tubes would be a better method, but afterward he decided to adopt smaller holes drilled in a plate, and constructed his third lamp, into which air was admitted through holes in the side of the oil-vessel, then through small holes from 2/25 to 1/22 inch in diameter into a space between two plates, when the air issued to the flame through a set of holes 1/12 to 1/18 inch in diameter punched in a metal ring. This lamp was tried underground on November 30th, 1815. In the final form of Stephenson's lamp, the punched plate was replaced by a gauze cylinder, which surrounded the glass cylinder; air was admitted through small holes in the ring to which the standards are fixed, or in a flange just above the ring. It has not been possible to ascertain the date when the wire-gauze was substituted for the punched plate.

Sir Humphry Davy.—Sir Humphry Davy was born near Penzance on December 17th, 1778. He was educated at the Penzance Grammar School, and was eventually apprenticed to Mr. J. B. Borlase, a surgeon and apothecary. He devoted his attention chiefly to chemistry, and in 1798 was apointed superintendent in the laboratory of the Pneumatic Institute at Bristol, where he investigated the properties of various gases, among them carbureted hydrogen. In 1801 he joined the Royal Institution as Assistant Lecturer in Chemistry, Director of the Laboratory, and Assistant Editor of the journals of the Institution, and on May 31st, 1802, was appointed Professor. He was elected a Fellow of the Royal Society in 1803, was secretary of that society from 1807 to 1812, and was elected president on November 30th, 1820. He was knighted in 1812, and created a Baronet in 1818. On resigning his professorship at the Royal Institution he was elected Honorary Professor of Chemistry. He died at Geneva on May 29th, 1829.

It was in August, 1815, that Davy met the Sunderland Committee, and after learning the conditions under which coal was mined and paying visits to the Hebburn and Wallsend Collieries he returned to London and commenced his investigations into the nature of fire-damp, which eventually led to the invention of his lamp. On November 9th, 1815, he read a paper before the Royal Society on "The Fire-damp of Coal Mines and on Methods of Lighting the Mines so as to prevent Explosion." In this he gave an account of his investigations into the explosive properties of fire-damp and the passage of flames through glass and metallic tubes. In his paper he stated:

"It is evident that to prevent explosions in mines it is only necessary to use air-tight lanterns, supplied with air from tubes or canals of small diameter, or from apertures covered with wire gauze placed below the flame through which explosions cannot be communicated and having a chimney at the upper part on a similar system to carry off the foul air, and common lanterns may be easily adapted to the purpose by being made air-tight in the door and sides, by being furnished with the chimney, and the system of safety apertures below and above."

In the paper three lamps are described; they appear to have been lanterns of thin plate with four glass plates in the side. In the first lamp air entered below the flame through a number of tubes ⅛ of an inch in diameter and one 1½ inches long, and the products of combustion escaped through a chimney composed of two open cones protected by a plate containing many small apertures. In the second lamp both inlet and outlet were protected by "safety canals" consisting of concentric metallic cylinders, one within the other, and separated from one another by annular spaces from 1/24 to 1/40 inch wide and 1 7/10 inches long. The inlet and outlet of the third lamp was protected by brass-wire gauze 1/200 inch thick, having apertures not more than 1/120 inch. A little more than a month later—namely, on January 1st, 1816—Davy announced to Dr. Gray his important discovery of the use of the gauze cylinder, and communicated his discovery to the Royal Society in a paper on January 11th, 1816. In this paper he describes his invention as follows:

"This invention consists in covering or surrounding the flame of a lamp or candle by a wire sieve; the coarsest that I have tried with perfect safety contained 625 apertures in a square inch, and the wire was 1/70 of an inch in thickness, the finest 6,400 apertures in a square inch, and the wire was 1/250 of an inch in thickness."

The first Davy lamps seem to have been tried at Hebburn Colliery on January 9th and 17th, 1816. Davy recommended the use of iron-wire gauze composed of wire from 1/40 to 1/60 of an inch in diameter and uncovered with any easily combustible metal; that in proportion as the inflammability of the gas increases, the apertures should be smaller and the radiating surface greater, and that several gauzes superposed might be necessary for continuous explosive mixtures. He pointed out that no aperture should be allowed in the lamp and the precaution of supplying a short gauze cap over the top of the main gauze cylinder. He also gave dimensions for the cubic contents of the lamp, recommending that the lamp should be from 8 to 10 inches high and from 2 to 2½ inches in diameter. Davy appeared to be aware of the limitations to the safety of his lamp, especially in currents of explosive gas, and recommended the use of twilled gauze or the protection of the gauze by a glass cylinder above the flame or a tin screen outside the gauze. On September 6th, 1816, he visited Wallsend Colliery and performed experiments with his lamps, and in pointing out the lessons to be learnt said:

"Now, gentlemen, you see the nature of the danger to which you are exposed in using the lamp, and I caution you to guard against it in the manner I have shown you. This is to show the only case in which the lamp will explode, and I caution you and warn you not to use it in any such case when you can avoid it without using the shield."

There is little doubt that Clanny considered himself the inventor of the first safe lamp, and a regrettable controversy arose toward the end of 1816 as to whether Stephenson or Davy was to be regarded as the first inventor of the safety-lamp. It is not necessary to go into the details of the controversy, but in regard to the merits of these two inventors Stephenson deserves great credit for his work. Unacquainted with the principles of chemistry and devoid of proper apparatus for experimentation, he was yet able to produce a lamp which seems to have been safe under the conditions for which it was designed. But to Davy's work the mining community is indebted for the safety-lamp as it exists to-day; not only did he invent a lamp which was within limits safe, but he laid down the principles of safety which have been followed and confirmed by subsequent investigators.

About the same time lamps were devised by Chevrèmont, John Murray (Lecturer on Chemistry at Hull), and R. W. Brandling. All these were similar, and consisted of inclosed lamps connected with long tubes through which air free from fire-damp could be brought from a distance.

Period 1816 to 1835.—The Davy & Stephenson lamps came into use shortly after their invention, and in 1818 the Davy was used in the north of England, Whitehaven, and Wales. It was also introduced into France, Belgium and Germany. During this period distrust arose as to the safety of the Davy lamp when exposed to currents of explosive mixtures other than those moving with low velocities. Davy had foreseen the danger and had suggested precautions that should be taken. There appears to have been a feeling of disappointment that since the introduction of the safety-lamps mortality due to accidents from fire-damp had increased. In 1835 a Select Committee on Accidents in Mines was appointed. The committee issued its report on September 4th of the same year, in which they stated that "ignorance and a false reliance" on the merits of the Davy safety-lamps "in cases attended with unwarranted risks have led to disastrous consequences," but a more extended use of the safety-lamp was recommended—"in some mines, now lighted by the ordinary means, the use of the lamp ought to be compelled by the owners." Among the lamps brought to the notice of the committee that of Upton and Roberts is commended. This lamp consisted of a gauze chimney of the Davy type inclosed in a glass cylinder; above the glass and fitting closely on to it was a metal chimney with perforated top. The air entered the lamp through horizontal holes just above the oil-vessel and passed through a double layer of gauze into a cone, by which it was directed on to the flame.

During this period Clanny brought out his fourth or "New" lamp. It was a Davy lamp fitted with telescopic extinguisher in three sections. When pushed up it was held in its place by a thin brass wire and exposed two thirds of the gauze cylinder. In an inflammable atmosphere the wire fused and let down the shield, leaving only a small scrap of gauze exposed. The flame of the burning gas was extinguished, but a small oil-flame continued to burn. Other lamps introduced during this period were a Muesler lamp, similar to the Upton and Roberts, lamps by John Martin. John Newman, John Dillon, and the "Refrigerating" lamp of Wood, all of which are briefly described in the paper.

Period 1836 to 1843.—During this period two important investigations into safety-lamps were carried out, namely:

1. By the Belgium Commission, appointed on April 13th, 1836.
2. By the South Shields Committee, appointed shortly after the explosion at St. Hilda Colliery, which occurred on June 28th, 1839.

Both committees tested safety-lamps from the point of view of safety and issued reports.

The Belgium Commission issued three reports—the first on April 25th, 1840; the second on August 31st, 1840, and the third on August 30th, 1841.

Among the lamps brought before the Commission and tested were the Davy, two lamps designed by Mueseler, the Cambrésy, the Dumesnil, and the Upton and Roberts. In the first report the opinion was expressed that the Davy lamp left much to be desired as regards safety, but that no lamp had been found to take its place except the Dumesnil. In the second report the Commission recommended that the Dumesnil, the Lemielle, and the now well-known chimney lamp of Mueseler be permitted for use, provided that their construction and dimensions were the same as the examples placed in the bureau of the Ingenieurs des Mines. The third report deals with trials made with the Mueseler lamps in practical working, and confirms the favorable opinion already expressed.

The South Shields Committee tested the following lamps: The Davy, Stephenson, Clanny (the fourth, fifth and probably sixth lamps), the Upton and Roberts, and the lamps of Henry Smith, William Martin, and Richard Ayre. The committee issued their report in 1843, and came to the following conclusions:

"No mere safety-lamp, however ingenious in its construction, is able to secure fiery mines from explosions, and that a reliance on lamps alone is a fatal error, conducive to those dreadful calamities which they are intended to prevent. . . . The naked Davy is with-

out a complete shield a most dangerous instrument.

"The best description of lamp to be employed is that on the principle of the Improved Clanny and the Mueseler lamps, the latter with a continuous gauze cylinder."

In 1840 Dr. G. Bischof, Professor of Chemistry in the University of Bonn, conducted tests on the Davy lamp and obtained results which agreed with those of Davy.

The lamps tested by the commissions are shortly described in the paper.

It was during this period that Clanny produced two more lamps (his fifth and sixth) and that Mueseler invented his lamp with the chimney. Clanny's fifth lamp consisted of an internal gauze cylinder, completely surrounded by an impervious metallic shield having glass and lenses in its side and only open at the highest part of the gauze cylinder for about 1½ inches from the top. There was ½-inch air-space between the cylinder and gauze and air could only enter the lamp after passing over the top of the shield. The lamp was subsequently modified by surrounding the portion opposite the flame with a "thick globular" shield of glass. The sixth lamp was constructed on the plan of the well-known Clanny—namely, with a glass cylinder surrounding the flame and a gauze cylinder doubled at the top fitted closely on to the glass.

The Mueseler lamp tested by the Belgian Committee introduced the chimney inside the gauze and was similar in construction to the unbonneted Mueseler of to-day. The air was taken in above the glass cylinder and had to pass through a horizontal gauze fitted between the top of the cylinder and the chimney. The unprotected glass cylinder surrounding the flame was considered to reduce the safety of the lamps.

Period 1844 to 1866.—During this period three Select Committees were appointed in England between 1849 and 1854 to inquire into accidents in mines. In the reports of committees appointed in 1849 and 1852 the Davy lamp was criticised on the score of giving defective light and want of security in a strong explosive current. The third committee pointed out that opinions as to its security varied, but the majority were in its favor.

Inventors appear to have been active in this period, for a considerable number of lamps of both types were introduced. These lamps are referred to in the paper. It is only necessary here to mention the "Jack" lamp, a shielded Davy in which the gauze was protected by a glass cylinder that extended from a short distance above the bottom of the gauze to the bottom of a short gauze cap or smoke cap. The "Tin-can" Davy was introduced in 1866, and consisted of a Davy lamp closed in a tin casing with a glass window. In order to improve the light given by the Davy the "Reducing" lamp was introduced, polished gauze being used and a polished cone being placed below the flame to reflect the light. Two gauze cylinders were used, the inner one "being placed at such a distance from the outer that the fire-damp inclosed between the cylinders (if the flame passes the first) explodes and may extinguish itself."

Period 1867 to 1879.—During this period several investigations on safety-lamps were conducted, the chief of which were those of the North of England Institute of Mining and Mechanical Engineers, of the Belgian government, of the Société de l'Industrie Minerale in France, and of Messrs. Smethurst and Ashworth. Several new lamps were introduced, but the only new type of lamp was the Gray. The tendency appeared to be to attain a high degree of safety by increasing the complexity of construction. The results of the various investigations showed the insecurity of the Davy in currents exceeding seven to eight feet per second, and in the report of the French experiments the use of the shield (*ocran*) is advocated. The Belgian Commission appears to have reported in 1873, and as a result the use of the Mueseler type of lamp was made obligatory in fiery mines. The experiments of Messrs. Smethurst and Ashworth confirmed Davy's results on restricting the diameter of the gauze cylinder.

Period 1880 to 1887.—This period was one of great activity in the investigation of safety in mines. The following commissions were appointed: The French Fire-damp Commission of 1878–1882, the Prussian Fire-damp Commission of 1880–1887, the Saxon Fire-damp Commission of 1880, and the British Royal Commission of 1879–1886. In addition experiments were carried out by the Midland Institute of Mining, Civil, and Mechanical Engineers in 1884, by Mr. A. R. Sawyer in 1884–1885, and by the Mining Institute of Scotland in 1886. The reports of these commissions contributed materially to the growth of knowledge on the subject. The principal results are given in the paper. The importance of the shield or bonnet in increasing the safety was frequently insisted on, but its use was in some cases objected to, as it concealed the gauze from inspection. A very large number of lamps were designed and submitted to tests. It is only possible to mention one of them here—namely, the Marsaut lamp. The first lamp introduced by Marsaut was a bonneted Boty or Clanny, with a chimney, derived from the Mueseler by suppression of the gauze diaphragm. On experimenting with his lamp by raising it into a glass bell containing illuminating gas and then lowering and stopping it opposite to the edge of the bell (in order to cause an internal explosion at the height at which the gas was mixed with air in suitable proportions), ignition of the gas in the bell took place at nearly every trial. This phenomenon, known as "l'effet Marsaut," occurred with several other lamps when similarly tested. As a result of these experiments Marsaut was led to construct the well-known Marsaut lamp. The gauze diaphragm and Mueseler chimney were replaced by an interior gauze. The large surface of this additional gauze offered means for the better cooling and escape of the gases. The gauzes were protected by a bonnet with holes at the bottom for the admission of air, which was taken in over the glass and had to pass through both gauzes and holes at the top for the escape of the products of combustion. This lamp did not show "l'effet Marsaut."

Period 1888 to 1913.—The most striking features of this period are the large number of official stations erected for testing safety-lamps and the improvement in apparatus used. Stations have been installed in Great Britain, at Eskmeals, in France and in Belgium, and in Westphalia, Silesia, and Saxony in Germany, while the Austrian station at Mahrisch-Ostrau, used by the Commission 1881 to 1891, appears to have been maintained. Experiments were also carried out at Karwin.

Considerable improvements have been made in the construction of lamps so as to secure strength in the various parts and to facilitate the operations of cleaning and assembling the lamps. Much attention has been given to the question of locking arrangements and magnetic locks have come largely into use. Arrangements for lighting lamps by electric means after they have been assembled have been largely adopted, and in Great Britain, France, and Belgium the efficacy of the bonnet has been fully recognized. In France, Belgium, and Germany the use of internal relighters is very generally approved, but not so in Great Britain. The question of illuminants has also received much attention, and even acetylene lamps have been introduced. Among the more important lamps of this period may be mentioned the Howat "Deflector" lamp, the Ashworth-Hepplewhite-Gray, the Thorneburry, the Fumat, the Body-Firket, the Wolf, and the Hailwood "Combustion-tube" lamp. As the result of recent experiments there has been a tendency to restrict the use of lamps by legislation to "permitted" lamps. This has been done in Great Britain, France, and Belgium. A number of the modern lamps are described in the paper, but it would appear unnecessary to do so here, as their construction is more or less familiar.

The authors have brought their paper to a close at the end of the year 1913 because they consider the history of the safety-lamp as commencing in 1813, although the Davy lamp was not invented until toward the close of 1815. Another reason which decided them to adopt this course has been the difficulty of writing about contemporary events, for since the outbreak of the great European war in August, 1914, the course of events has not been normal, and possibly the development of the safety-lamp has been in consequence arrested.

Complete Photo-Electric Emission

When light of short wave-length falls on a metal it causes an emission of electrons. All bodies emit light when raised to a sufficiently high temperature, so that an emission of electrons will occur from a glowing body due to its own light. This emission of electrons is called the "complete photo-electric emission," as it is excited by the complete radiation with which the material is in equilibrium at the temperature under consideration. This emission of electrons will form part of the thermionic current, and it is of interest to find out whether it forms any considerable fraction of the observed effects. Theory indicates that the purely thermionic current and the photo-electric current vary with the temperature in the same way, and experiments with platinum show that the thermionic current is always thousands of times greater than the complete photo-electric emission.—*Philosophical Magazine.*

Cows', Goats' and Human Milk

Whereas human milk contains no insoluble phosphate, that of goats contains tricalcium and di- and trimagnesium phosphates, and the insoluble phosphate in cow's milk is the diacalcium salt. As regards soluble phosphates, human milk contains monomagnesium and monopotassium phosphates; goat's milk, monopotassium phosphate, and cows' milk, the monomagnesium and dipotassium salts. The phosphate content of human milk is much below that of the other two kinds. Potassium citrate is present in all three kinds; cow's and human milk contain also sodium citrate. Cow's milk contains the most chloride, goat's milk the least. The latter contains calcium, potassium, and sodium chlorides, the two others only calcium chloride. The amount of total salts in human milk is about one third of that in the other two sorts; the number of salts is greatest in goat's milk and least in human milk.—*A. W. Bosworth and L. L. Van Slyke, in Journal of Biological Chemistry.*

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