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Marking rough diamonds before sending them to the splitter.

DIAMOND CUTTING IN AMERICA.—**[See page 232.]**

The Mechanism of Chemical Change in Living Organisms*

How a Slow Reaction Can Be Made to Go Faster

By Prof. W. M. Bayliss, F. R. S.

If we take a general view over the large field of chemical reactions known, we notice that there is a great variety in the *rate* at which these reactions take place. Some, and especially those in which electrical forces play a part, reactions between inorganic ions, are practically instantaneous. They are familiar to all in the precipitations of the analytical chemist. Others, such as the hydrolysis of cane-sugar by water, are so slow as to be incapable of detection at ordinary temperatures, unless a very long time is allowed. There are, moreover, all possible stages intermediate between these extremes. Reactions between carbon compounds are, generally speaking, comparatively slow; but, as the name "organic" indicates, they are the characteristic chemical changes of the living cell.

Early workers in the domain of physiological chemistry—Schönbein, for example—were struck by the fact that reactions which require, in the laboratory, powerful reagents, such as strong acids and high temperatures, to make them take place at a reasonable rate, occur rapidly in the living organism at moderate temperatures and in the presence of extremely weak acids or alkalis I may refer to the decomposition of proteins into their constituent amino-acids, which is a part of the normal process of digestion, but, when ordinary laboratory methods are used, requires boiling for several hours with concentrated hydrochloric or sulphuric acid.

The problem before us, then, is to discover how a slow reaction can be made to go faster. The most obvious and well-known method of doing this is by raising the temperature; but this is clearly out of the question in living cells. Another possibility is to make use of mass action, increasing by some means the effective concentration of the reacting substances; in this way the number of contacts per unit time would be raised. This is possible in the cell. There remains a third, the formation of an intermediate compound with another substance. This compound may be supposed to be both formed and again decomposed at a rapid rate, so that the total time taken is much less than that of the original reaction.

Now it is evident that something of the kind contemplated by these two latter possibilities is at the bottom of the process called "catalysis" by Berzelius. This chemist directed attention to the numerous cases known, even at his time, where the presence of a third substance brings about an enormous acceleration of a reaction, without itself taking part in it, so far as appears at first sight; at all events, this third substance reappears at the end unchanged. An example is the effect of finely divided platinum on hydrogen peroxide. Similar phenomena were known to Faraday, and described by him about the same time, but without giving them a special name.

Agents of this kind were soon discovered to be present in living cells. Such catalysts are called, for convenience, "enzymes," as suggested by Kühne, although there is no real scientific necessity for the name. That of "ferments" is still sometimes used, and is not now liable, as it was in Kühne's time, to cause confusion by application to living microbes.

Since catalysts are, as a rule, found unchanged at the end of their work, it is clear that they do not themselves afford energy for the purpose. Indeed, the energy change of a catalysed homogeneous system is the same as that of the reaction when proceeding at its ordinary slow rate. How, then, do they act?

The first thing to note with respect to enzymes is that they are capable of activity in media in which they are insoluble. Whatever may be the nature of this activity, therefore, it is exerted by the surface of the catalyst. We may then reasonably ask, as the most obvious hypothesis, is there ground for holding that the increased rate of reactions brought about by enzymes is effected by increase of concentration of the reagents at the surface and consequent acceleration of the reaction by mass action? We know that substances which lower surface energy of any form are concentrated at such boundary surfaces. The process is well known as "adsorption," and is a consequence of the operation of the principle of Carnot and Clausius, which states that decrease of free energy always occurs, if it is possible for it to do so. In fact, such an explanation was given by Faraday of the effect of metallic platinum in causing combination of oxygen and hydrogen gases. Although the name "adsorption" was not used in this description, Faraday had very clear ideas of the process, and gives several interesting cases. He showed that the necessary condition for the activity of platinum in the case referred to is a chemically clean surface, in order that the gases may condense on it. It matters not whether the removal of deposit is effected by mechanical polishing; by the action of acid or alkali; by oxidation or reduction—making it either anode or kathode in an electrolytic cell will serve. It should be mentioned that this view did not receive universal acceptance, but the fact that it recommended itself to the keen insight of Faraday is powerful evidence in its favor.

I would not venture to state that this hypothesis is yet in a position to explain all the facts met with in the action of enzymes themselves, but it is remarkable how many receive a satisfactory account. We are at once confronted by the difficulty of the considerable number of different enzymes. But we must not forget that the adsorption is controlled by a great number of factors in addition to mechanical surface tension. All those properties which suffer modification at phase boundaries play their part—electrical charge, solubility, compressibility, even chemical reaction itself, may be mentioned. Moreover, as Hardy has pointed out, the act of condensation in itself may well be accompanied by the manifestation of molecular forces which result in increased chemical potential of the reacting substances. It is clear that experimental decision of the questions involved is almost impossible until we have in our hands pure preparations of enzymes. We cannot as yet exclude the possibility of the formation of intermediate *chemical* compounds between enzyme and substrate, but their existence has not been demonstrated, and what I may venture to call Faraday's view has the advantage of simplicity, and thus the support of William of Occam's "razor."

The important question of the synthetic action of enzymes demands a little attention at this point. All reactions may be regarded as being, in principle, reversible or balanced, and the greater part of those of the living organism are found experimentally to be so. If we take for consideration those enzymes the action of which consists in the addition or removal of the elements of water, we find that, as would be expected from the law of mass action, the position of equilibrium in the presence of a large excess of water is very near to that of complete hydrolysis, and this is the state of affairs in the usual laboratory experiments. On the other hand, the less water is present, the greater is the preponderance of the opposite—synthetic—aspect. Take the classical case of ethyl acetate. If the ester and water are mixed in molecular proportions, hydrolysis to acid and alcohol occurs until two-thirds of the ester are decomposed. Moreover, the same final composition is obtained if we commence with acid and alcohol, and so work in the other direction. But these reactions proceed by themselves with extreme slowness, taking months before coming to an end. But the presence of a catalyst, such as mineral acid, brings about equilibrium in an hour or so, and we notice that it is the same as the spontaneous one. An enzyme, known as lipase, also brings about equilibrium rapidly. The important point in respect of the mechanism of living cells is that by changing the available amount of water, the reaction may be made to proceed in either direction at will. The series of curves given by Armstrong and Gosney (*Proc. Roy Soc.*, 88 B. p. 176) show this fact very clearly. Further, if the equilibrium is brought about rapidly, even if to any position except that of complete change in one or the other direction, the enzyme must accelerate *both* reactions, and any hypothesis of special "synthesising" enzymes is superfluous. This is essentially the position taken by van't Hoff in the work with which he was engaged at the time of his death. What is required, then, is a means by which the cell is enabled to change the available water at the disposal of reactions occurring therein. We do not as yet know the precise nature of such mechanisms, but there is reason to believe that they are provided by changes in the surface area of colloidal constituents or in the power of imbibition possessed by certain contents of the cell.

We here come across an interesting problem which cannot be said to be solved satisfactorily at present. We have seen that the equilibrium position of an ester system when reached rapidly under the action of a soluble catalyst is the same as the spontaneous one. But there is a certain difference when a heterogeneous catalyst, or enzyme, is used. Nevertheless, the equilibrium is a true one, being in the same position when approached from either end. The amount of butyric acid combined as amyl ester in a particular system under acid catalysis was found by Dietz to be 88 per cent of the total; under the action of the enzyme lipase it was only 75 per cent. This fact has given rise to various suggestions, and has troubled people's minds because it appears to give a possibility of evading the second law of energetics. Now, it was pointed out to me by Prof. Hopkins that, on the hypothesis of a rapid attainment of equilibrium by condensation on the surface of the enzyme, it is necessary, if the natural equilibrium is to be unaltered, that adsorption of all the components of the system should be the same proportion of each, because the position of equilibrium must be the same on the surface of the enzyme as that which results in the body of the solution. In the presence of a large excess of water, it does not seem likely that a difference of equilibrium owing to this cause could be detected. But this should be possible when the equilibrium position is nearer the middle, so to speak, and I am at present engaged in experiments on the question. At any rate, difference in adsorption may be the cause of the phenomenon of Dietz. It would simply imply that the water is adsorbed by the enzyme in relatively larger proportion than the other constituents of the system. It should be remembered that the solvent in these experiments was amyl alcohol containing about 8 per cent of water, and, as Arrhenius has shown, all substances present are adsorbed, although the laws governing the relative proportion of these various substances are not yet completely worked out.

We see, by consideration of the facts relating to the action of enzymes, how important a part is played by changes in the rate of reactions, and there are two further points to which attention has been directed by Prof. Hopkins. Take, first, a series of reversible reactions in which the products of one form the starting point of the next following:

$$A \rightleftarrows B \rightleftarrows C \rightleftarrows D \rightleftarrows \text{etc}$$

If the rate at which *B* is converted into *C* is greater than that at which *A* changes into *B*, it is obvious that the amount of *B* present at any moment may be extremely small, although the whole of the final products have passed through the stage. The fact warns us from estimating the importance of any particular constituent of the cell by the quantity to be obtained.

The second point is this. Suppose that there are two independent reversible reactions, both leading to the same product, *C*.

$$\left.\begin{array}{l} A \rightleftarrows \\ \\ B \rightleftarrows \end{array}\right\} C$$

and that $A \rightarrow C$ is more rapid or easier than $B \rightarrow C$. This latter reaction will be practically absent, being balanced by the excess of *C*. But, if the former reaction is abolished by removal of *A*, then $B \rightarrow C$ will take place in proportion as *C* is used up in other reactions. Thus, under special conditions, a reaction may take place which is not detectable under normal conditions, although capable of taking place.

One of the most difficult questions is the manner in which the various components of the cell are prevented from entering into chemical reaction except when required. Enzymes, for example, are not always in activity. The conception which states that the cell consists of numerous minute "reaction chambers," separated from one another by membranes, seems to present most possibilities. These membranes must be regarded as capable of removal and of reconstruction, or reversible as regards their permeability. The food vacuoles of an Amœba may serve as an illustration of such chambers on a comparatively large scale. In these vacuoles digestion processes are going on independently of other reactions in various parts of the same cell protoplasm, although this latter behaves as a liquid.

*Abridged from a discourse delivered at the Royal Institution. From *Nature.*

The general conclusion to which we arrive is that velocity of reaction plays an exceedingly important part in the regulation of cell mechanics. I venture to think that the conception is destined to replace static points of view, such as that of "lock and key" or the fitting together of molecular groupings. That there is still very much to be discovered is obvious. We have to find out how the living cell is able to modify and adjust together the large number of reactions known to the chemist. The study of the methods by which the rate of these reactions is affected is one of the most valuable of those accessible to us.

The Sense of Proportion

Applying the Principle of Similarity to the Designing of Machinery

One of the most interesting and difficult principles in engineering science is that known as "the principle of similarity." It is the principle by aid of which the design of a small model may be made the basis of the design of a full-sized machine.

At first sight it would seem that the principle of similarity is nothing more than simple proportion, and that one and the same set of working drawings might be used for a successful design of any size by simply changing the scale. This is a fallacy into which we all are but too apt to fall, and it leads to many a faulty design. The fact that in a multitude of cases the simple proportion rule is quite sound does not enhance the danger of its general application. Common sense seems to tell us that the same relative proportions which serve for a small machine will serve also for a big one. We overlook the instances so abundantly before us which show how often the rule of simple proportion fails to apply. We see a child of three carrying another as big as itself—a feat quite beyond the strength of a full-grown man. In proportion a child is many times stronger than a man. We see a tiny drop of water suspended like a ball of glass—a thing quite impossible for a large mass of water. A boy bounces a glass marble upon the stone pavement—a glass ball ten times the size would be smashed to atoms. At the seaside we build bridges of sand that span miniature rivers, but we know that if the rivers were more than a few inches wide such bridges would not support their own weight. We use thin paper to kindle a fire—thick paper will not inflame. A glass rod like a lead pencil readily breaks—a glass rod like a human hair can be tied in a knot. A spinning-top made of lead may spin at 1,000 revolutions per minute, but a similarly proportioned fly-wheel of lead would fly to pieces at the same revolutions per minute. The steel fly-wheel of a motor bicycle runs at 2,000 revolutions per minute, while a large fly-wheel of steel, similarly proportioned, would fly to pieces at even 1,000 revolutions per minute.

All these are instances in which we have learned by experience that the law of simple proportion does not hold. Experience rather than thought has taught us what to expect in such cases.

Historically the mathematical consideration of this great principle dates back perhaps not more than fifty years, the first notable paper upon having been read in 1875 by Prof. James Thomson, brother of Lord Kelvin.

One of the obvious instances in which nature has emphasized the inapplicability of the rule of simple proportion is in the structure of animals. A greyhound with long spindly legs is well proportioned. An elephant with short thick legs is well proportioned. But a greyhound the size of an elephant could not support its own weight, while an elephant the size of a greyhound would be disproportionately sturdy; it would be strong enough to carry a great shell, like a tortoise.

An understanding of these simple instances is all that is necessary to enable us to examine the application of the principle of similarity, in a general way, to the design of a motor car. The strength of a wire or rod of steel depends upon the area of its cross section, and in a similar way the strength of a man's limbs depends upon their section. Now if a man's linear dimensions were doubled the section of his limbs would become four times as great as before, and they would be capable of supporting a body four times as heavy as before. But the man's weight would have increased eight fold, for his girth would have been doubled, his section quadrupled, and his height doubled. Thus the limbs which would be but four times as strong as before would be called on to support a body eight times heavier. The giant would surely collapse. A well-proportioned giant should be as different in proportion from an ordinary man as an elephant is different from a dog.

Mathematically put the explanation is obvious: the weight of a body goes up with the cube of its linear dimensions, while its cross section goes up only as the square.

What could be more strong and reliable than a steel bicycle ball? Yet it can be easily shown that a very large ball of steel would positively collapse under its own weight.

A wooden plank will bear a man across a ditch. A similarly proportioned wooden bridge across a river would collapse under its own weight.

One day I stood admiring the well-known quarter scale model of the Silver Ghost, that famous Rolls-Royce that went a score of times from London to Edinburgh with sealed bonnet, and wondered that the fairies had not yet stolen it for a Queen Titania tour.

Someone suggested that Oberon's engineers had turned it down as a bad design, and thereupon followed a lively discussion. All agreed that the design of the *original* Silver Ghost was good enough for man or fairy. As to this model the majority maintained that since it might be regarded as the original seen from a distance (its proportions being the same in every detail) its design must therefore be as perfect as that of the original.

It was agreed that in comparing the design of the model with that of the original the following assumptions ought to be made:

1. That the same materials are used for corresponding parts in each case.
2. That the revolutions per minute of all rotating parts are the same in each case.
3. That the maximum and the mean pressures inside the cylinders are the same in each case.
4. That fairies are proportioned like men and are of the same specific gravity.

The results of the comparison, the steps in which are given below, were the following:

1. That the engine is, relatively, four times as powerful in the small car as in the original.
2. That the moving parts of the small engine are unnecessarily strong.
3. That the radiator is much too big.
4. That the frame of the chassis is much too heavy.
5. The carriage springs and those of the cushions are much too strong.

The steps in the argument may be set down briefly, thus:

Horse power of the model.—The cubic capacity of the cylinders being one sixty-fourth and the revolutions per minute the same, the gasoline used should be one sixty-fourth and the horse-power one sixty-fourth.

Weight of the model.—Every cubic inch of material (including passengers) in the large car becomes one cubic quarter-of-an-inch, that is one sixty-fourth of a cubic inch, in the model. Hence the weight of the model must be one sixty-fourth of that of the car.

Speed.—The circumference of the road wheels being one quarter and the revolutions per minute equal, the road speed of the model must be one quarter of that of the large car.

Thus far, then, we see that while the horse-power per ton weight of car is the same, the model travels only one quarter as fast as the large car, and possesses, therefore, four times as much power as is required.

Stresses in the cylinder walls.—These will be the same.

Stress in the connecting rods.—This will also be the same except that part of it which is due to the reciprocation of the moving parts. On account of the centrifugal forces the stress in the connecting rods of the model will be only one sixteenth as great as in the large car. The centrifugal force is directly proportional to the mass of the reciprocating parts, the length of the stroke and the square of the revolutions per minute.

Stress in the propeller shaft.—The revolutions per minute being the same in each case, while the horse-power is one sixty-fourth, it follows that the torque in the propeller shaft will be one sixty-fourth.

The diameter of a shaft transmitting torque should be in proportion to the cube-root of the torque. Since therefore the torque for the large car is sixty-four (that is four cubed) times that of the model, the diameter of its shaft should be four times as great. Thus we see that the propeller shaft is correctly chosen.

Cooling surface of the cylinders and radiator.—The surface area of the cylinders and also of the radiator of the model is one sixteenth of that of the big car, whereas the volume of gas burnt is but one sixty-fourth. In proportion, therefore, the model has four times as great cooling surface as the big car. It is true that the slower road speed of the model will make the cooling less efficient, but, on the other hand, since the engine has four times the power required it will seldom run on full throttle.

Hill climbing.—If the large car can just climb, when fully loaded, a gradient of one in three, the model should climb a gradient of four in three—something a good deal worse than the side of a house. For while the horse-power per ton weight is the same as for the car the speed of the model is but one quarter.

Frame and springs.—The modulus of the section of the girders of the small frame will be one sixty-fourth of that for the large car's frame and the length one fourth. It follows that the frame of the model is four times the strength needed.

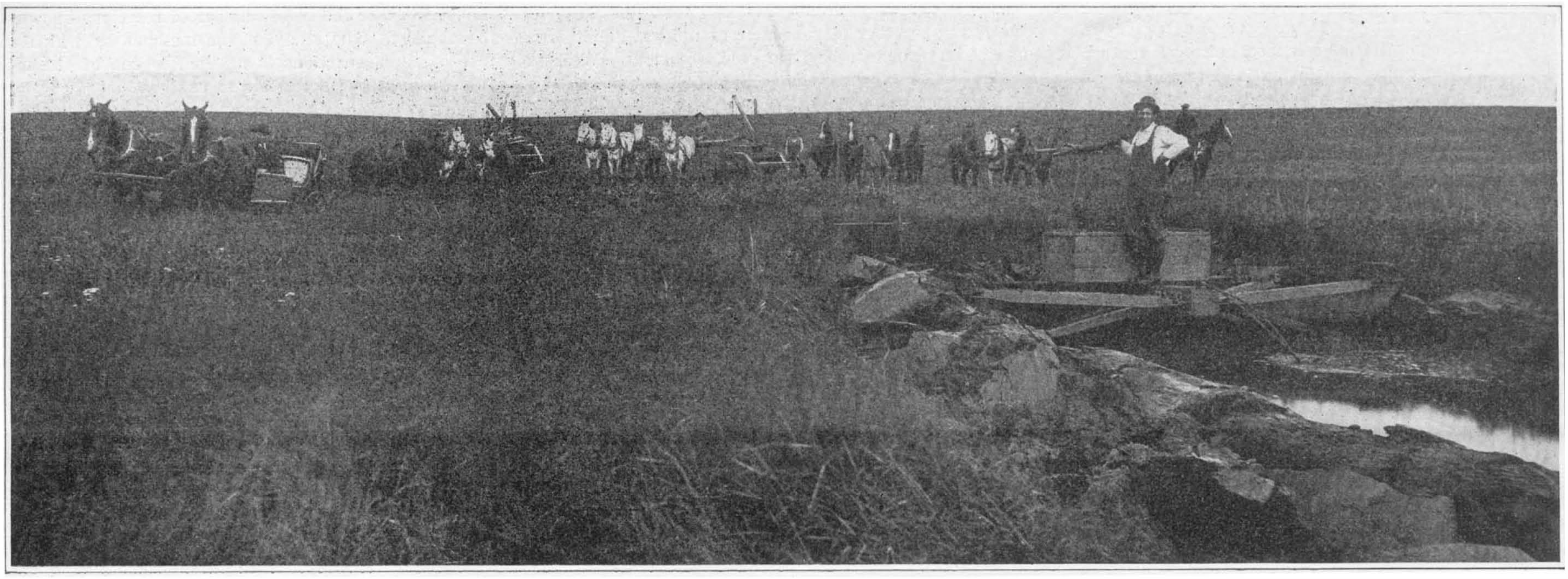
The carriage springs and those of the cushions are likewise four times too strong, it being assumed that, with correctly proportioned springs, the deflection of the springs of the model, due to the weight of the loaded car, ought to be one quarter as great as for the large car.

Some of those who have read thus far will be feeling impatient with objections. One real objection there is to these arguments, namely, that the assumption of equal revolutions per minute for the two cars ought not to be made. From the point of view of the discussion, however, the assumption was not at all unfair, for if the little car represented the big car seen from a distance, the one quantity not affected would be the revolutions per minute.

Engineers know, however, that if instead of the revolutions per minute (that is to say, the angular velocity) they maintain the linear velocities of the moving parts constant, the law of simple proportion is entirely legitimate as applied to the design of engines except in so far as concerns the stresses in various parts due to the dead weight of those parts. If, for instance, the design of the Silver Ghost be examined under the assumption of equal piston velocities, equal peripheral velocities of the wheels, and so equal road speeds for the two cars, it will, indeed, be found that the engine of the little car is as well proportioned as that of the big one, all parts in the one being stressed to the same degree as in the other. But as regards the suitability of the engine to the car, matters are even worse than before. The horse-power per ton in the model will now be four times as great as in the original car, and the hill-climbing capabilities will be, in point of speed, even more freakish than before. In fact, if the big car could climb a hill of one-in-sixteen on top speed at 40 miles per hour, the little one should climb a one-in-four at 40 miles per hour!

It should be noted, however, that equal piston velocities demand that the engine of the small car shall make four times the revolutions per minute of the large engine.

The results of all these considerations are important in showing that "sense of proportion" with which we all are gifted, more or less, must be employed warily. If we see a bridge, or an arch or a building, our sense of proportion tells us whether or not such object is well designed, but we are apt to overlook the fact that our conclusion is based upon our estimate of the absolute size of the object, and that if the size differs greatly from our estimate of it our sense of proportion will have deceived us. The working drawings of a *bridge*, though made accurately to scale, cannot appeal to our sense of proportion unless the absolute scale of the drawing is known. The working drawings of a *machine* cannot appeal to our sense of proportion unless in addition the velocities of the moving parts are known. And in such a complicated structure as a motor car, in the construction of which not alone bridge work as well as moving parts are involved but also a prime mover, much of the energy output of which is expended in raising or accelerating the mass of the structure itself, our sense of proportion is apt to mislead us unless we know both the absolute scale and the linear velocities of all the parts.—*Technicus, in the Auto Motor Journal.*



A big ditching plow at work, being hauled by three capstans, each operated by four horses.

Plowing Drainage Ditches

A Monster Implement Successfully Operated in the Middle West

By Frank C. Perkins

THE VALUE of many tracts of rich, low-lying bog lands for agricultural purposes has long been recognized, but the expense of the extensive drainage ditches necessary to reclaim them has been beyond the means of the average farmer. To meet these conditions a method of excavating good sized ditches by plowing has been gradually developed in some sections of the Middle West that has enabled many a farmer to utilize large tracts of land that have heretofore been unavailable.

For small drainage problems plowed or hand-dug ditches have long been made; while in large developments the floating dredge and the so-called land dredge have been employed to excavate good sized canals. But there is a large amount of drainage that requires ditches intermediae between these sizes, and for these a ditching plow was invented about forty years ago in western Indiana. It has a double mold broad and cuts a ditch about 4 feet wide on top and 2 feet deep, with a bottom width of less than 1 foot. To draw this plow eighty oxen were used, making the ditch at one cut.

The next step in the development of this type of ditching machine was to pull the plow with homemade wooden capstans and manila rope. Later wire rope was used, with larger capstans of steel and wood, having self-anchoring devices. Horses were used to haul the outfits and to turn the capstans. As more powerful pulling equipment was developed, the plows were enlarged and built of steel. This type of ditching machine finally developed into a standard outfit, consisting of one plow and two capstans, using several thousand feet of steel cable with each rig,

With this outfit the plow will cut a ditch 8 feet wide on top, 18 inches on the bottom, and about 3 feet deep. It is drawn by two ¾-inch steel cables, one to each capstan, both being operated at the same time. It makes a ditch with one cut in land, dry or under water, and places the earth excavated on both sides of the ditch, pushing the earth back so as to leave a clean berm of 3 feet. The two capstans used to draw the plow are self-anchoring, and have 14-inch vertical drums, each holding 1,000 feet of cable. Four heavy horses are used on each capstan, working abreast and pulling at the end of a sweep that is attached direct to the drum. This sweep is usually about 24 feet long, and the horses describe a circle nearly 50 feet in diameter in order to wind in 3 or 4 feet of cable. The work is so severe that relays of horses are used, and there are usually about 20 horses with each outfit.

These horse-driven ditching plows cut about 100 rods of ditch per day. In Wisconsin they frequently cut 50 miles of ditch in one season at a contract price of from $1.25 to $2.00 per rod of ditch, depending upon the character of the soil. Ditches made in stony or timbered lands are more expensive. Gasoline power-operated capstan plows are now used, since the gasoline engine has entered the field as a source of power.

One of the illustrations shows a gasoline engine supported by two long caterpillars 30 inches wide carrying a cable drum. Two anchor sprags, 2 x 10 feet, are attached to the tractor near its forward end, one on each side. They are held at the proper angle by heavy chains attached to the frame of the tractor. These anchors hold the power capstan stationary when the plow is being pulled forward to cut the ditch. The 1⅜-inch steel pulling cable is wound upon a large built-up cast-steel drum attached to the rear of the machine. This drum is 24 inches long, 16 inches in diameter with flanges 36 inches in diameter.

It is driven from the main driving shaft of the tractor by two heavy link-belt chains, and is so back-geared that when the 60 horse-power motor is running at its normal speed the drum winds in the pulling cable at a rate of 14 to 18 feet per minute, depending upon the amount of cable on the drum. The drum holds about 1,000 feet of cable. When a greater length is required, on account of inaccessible grounds, etc., removable sections of 500 or 600 feet of cable are used to attain the desired length.

It is claimed that the tractor with power capstan has proved so successful that others are now being built to be put in the contracting field next Summer. It has been found that the pulling power is so much greater than that of the horse-power machines that the size of the plow can be increased. This plow will cut ditches 2 feet wide on the bottom and 3½ feet deep.

The tractor, besides furnishing power to do the ditching, is also used to haul the plow (which weighs 4 tons when mounted on its removable trucks) from place to place, together with a wagon loaded with cable and supplies, and a boarding cabin mounted on wheels. It takes this outfit over ordinary country roads at the rate of about 2 miles per hour. The machine weighs about 15 tons, but owing to its large bearing surface, it can travel under its own power over swamp lands too soft to support a team. It is driven by a 4-cylinder, 4-cycle gasoline engine of 60 horse-power, which also furnishes power to drive the winding drum.

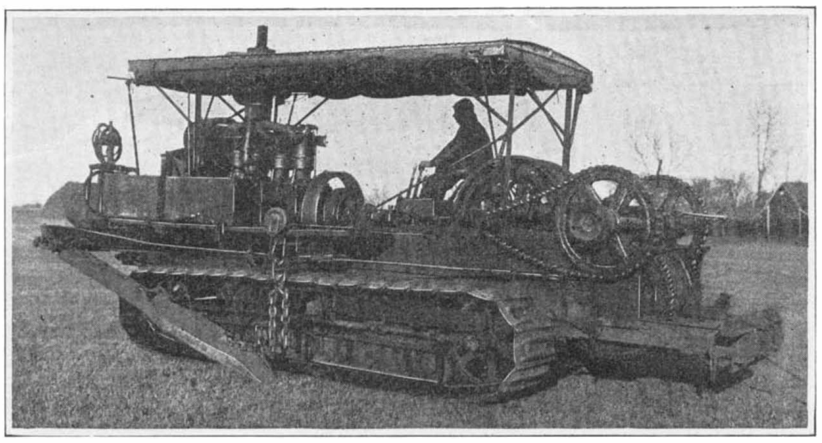
In operation the plow is left at the starting point of the ditch, the cable attached to the beam of the plow. Then the tractor, with its power capstan, moves ahead to some point on the line of the ditch to be cut, paying out the cable as it advances. When this point is reached the traction gear is released and the winding apparatus to the drum is thrown into gear. The anchors are released, allowing the points to drop on the ground. As the cable to the plow becomes taut it draws the machine backward, causing the anchor flukes to enter the ground until the tractor with its capstan becomes firmly anchored. When all the cable is wound on the drum, or a change in the direction of the ditch is to be made, the winding gear is thrown out of action and the tractor is moved to a new position.

This ditching outfit is operated by one man and a helper; one man rides on the plow, and a team of horses with a driver is used in hauling supplies to the camp and to the machine. A cook in the portable cabin on wheels furnishes the food for the crew.

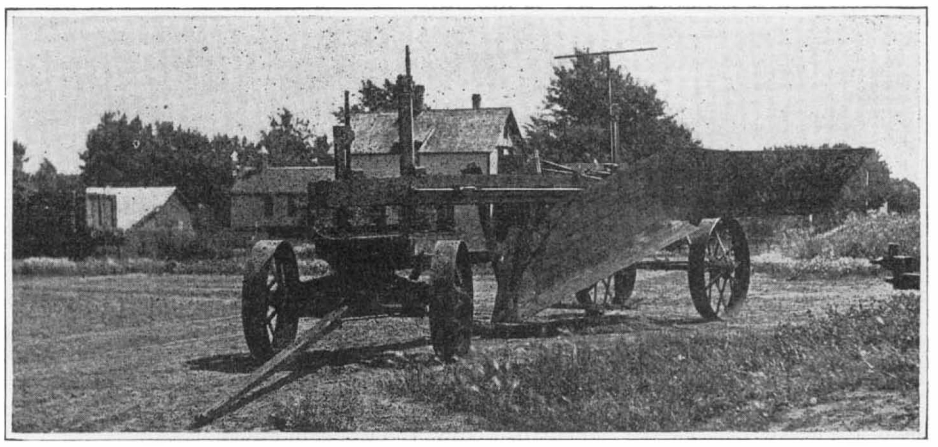
Motor Road Train

THERE is now at work in Yorkshire a motor road train fitted with the electro-mechanical variable speed gear designed by the Thomas Transmission system. It consists of a tractor and two trailers, weighing in all about 14 tons, and the noteworthy feature of the arrangement is that when a large tractive effort is required, corresponding to the periods when the low gear of a motor-car with an ordinary mechanical gear box would be used, a portion of the power developed by the gasoline engine, which gives 75 horse-power at 1,000 revolutions per minute, is converted into electricity and transmitted to electric motors in the trailers, which thus become self-propelled. The proportion of the power transmitted electrically is largest at starting, but is diminished as the speed increases until finally the electrical part of the apparatus is cut out and all the power is transmitted mechanically to the driving axle of the tractor, which then simply hauls the trailers. This condition, which is reached through ten intermediate speeds, corresponds to the top speed of a motor-car, and as it is the one which holds, on ordinary roads, for perhaps 90 per cent of the total running, it follows that the losses due to the electrical transmission occur during only a fraction of the time and are not continuous, as they would be if electrical transmission were relied upon solely. The necessary cables pass through tubular drawbars or coupling rods, which also effect the steering of the trailers. The steering of the first trailer is governed by the position of the rear axle of the tractor, and that of the second trailer by the position of the rear axle of the first trailer, with the result that even in going round the sharpest corners all the vehicles follow the same track. If the train has to be run backwards, the second trailer has to be steered by an operator walking beside it, and then its course governs that of the first trailer and of the tractor.

There are brakes on all the vehicles, those on the trailers being controlled electrically from the driver's seat on the tractor. The train is capable of carrying a net load of 36 tons, but the normal net load recommended is 20 tons, equivalent to a gross load of 34 tons. Under the latter condition a maximum speed of 15 miles an hour may be obtained on good level roads, though the normal speed recommended is 12 miles, and the maximum gradient that can be climbed is one in 10, at a speed of 2½ miles an hour. Tests indicate that with gross loads of the order of 30 to 45 tons on good roads on a give-and-take route with reasonable gradients about 75 or 80 ton miles can be obtained from a gallon of gasoline. The number of vehicles is not limited to three, and designs have been got out for a five-vehicle train, with an engine of 140 horse-power and a tare weight of 23 tons. This would be able to carry a maximum of 60 tons, but the normal net load recommended for it would be 36 tons, and with that it would be able to climb a gradient of one in 3½ at a speed of one mile an hour.—*Engineering Supplement of the London Times.*



A gasoline tractor fitted with a powerful winch for hauling the plow.



A big ditching plow mounted on wheels ready for transportation.

Wood Flour

By Frederick W. Kressmann, Chemist in Forest Products, Forest Products Laboratory, Madison, Wis.

Wood flour is ground or milled wood that has been screened so as to remove coarse particles and also to give particles having some uniformity in size. Wood flour is usually sold as 40, 60, or 80 mesh,* although one large foreign purchaser has the following specification for dynamite flour:

20 per cent must pass through an 80 mesh screen.
50 per cent must pass through a 60 mesh screen.
100 per cent must pass through a 50 mesh screen.

The different properties of a good wood flour are: 1st, it must be white; 2nd, it must be light and fluffy; 3rd, it must be absorptive.

All industries in which wood flour is used (and these will be considered in greater detail later), require a white or very light cream-colored flour, although absorptive qualities are demanded in a large degree only in dynamite flours. Color and weight considerations, therefore, limit the species of wood which may be used to the white, light, non-resinous conifers and to the white, broad-leaved woods like aspen and poplar. Spruce, white pine and poplar are the species most often used. The wood must be barked before grinding and round wood, slabs (barked) and sawdust free from bark may be used.

The grinding of the wood is performed in two distinct types of apparatus, either stone mills or steel burr roller mills. In Europe, particularly Scandinavia, where a great deal of wood flour is made, the stone mills seem to be used exclusively, and most of the early plants in this country use this type of mill. The stones are from 40 to 60 inches in diameter and only the lower stone is driven, the upper one being stationary. The mills are driven with water power turbines, since flour produced with other sources of power cannot compete with Norwegian flour ground by water power.

The wood after barking is first reduced to chips by means of the usual type of chipper or hog. These chips along with a certain proportion of the screenings are fed to the mills, which are completely enclosed (with the exception of an opening at the top) with an iron or steel cover. Sufficient steam or water is added to prevent firing, and also to keep down the dust. The fine stuff from the mill is then drawn or blown through iron pipes or sheet metal ducts to the screening apparatus, which may be of several types, and which may be either bronze wire or silk bolting cloth, for both are used. After screening the flour is packed either in compressed bales (the imported material comes in this way) or else is sacked with automatic sacking and weighing machinery.

Mills of the above type require from 45 to 50 horse-power per 24 hours per ton (from 1,200 to as high as 1,500 horse-power hours per ton) of flour produced, the power requirement being about the same as in the production of mechanical ground wood pulp.

Another type of mill was developed on the Pacific Coast about 25 years ago, and was designed especially to handle sawdust as a raw material. This grinder consists of a number of pairs of corrugated chilled steel rolls which turn towards each other. One of the rolls rotates three times as fast as the other, thereby actually cutting the sawdust which comes between them. The slower roll has its corrugations arranged so that they form pockets to hold the dust while the faster roll does the cutting. There are three stands of rolls, the corrugations being progressively finer on each stand.

The sawdust is screened before reaching the first rolls so as to remove slivers, small blocks, etc. It is then passed over a strong electric magnet to pick out any particle of iron or steel present, and is also screened through bolting cloth between each pair of rolls to remove material of suitable fineness. The production of wood flour from sawdust in this type of mill requires only from 20 to 25 per cent of the power required with the stone mills.

Before the war Norwegian wood flour was delivered at our Atlantic ports for from $12.50 to $15.00 per ton, and domestic material sold in competition therewith. The domestic production is largely controlled by one concern, although mills are scattered all over the country from Maine to California wherever the combination of proper wood and water power is available.

*Screens of bronze wire having 40, 60 or 80 meshes per linear inch.

USES.

The principal uses for wood flour are in the manufacture of dynamite, linoleum, artificial plastics and flooring, and as an inert absorbent in many industries.

DYNAMITE.

Dynamite consists essentially of nitroglycerine absorbed in some porous material. For this purpose wood flour, wheat flour mill refuse and infuserial earth (Kieselguhr) are the principal materials used, and wood flour is the one commonly used to-day. In addition, a certain amount of oxidizing material, either sodium or potassium nitrate with traces of calcium carbonate, magnesium carbonate, or zinc oxide are used. The latter materials are added to neutralize any free acid that may be formed by the decomposition of the nitroglycerine in long storage.

The composition of typical dynamites is as follows:[1]

Moisture		1.4
Nitroglycerine	40	60.6
Sodium or potassium nitrate	44	18.6
Wood flour	15	18.2
Calcium carbonate	1	1.2

A dynamite flour must be both white and highly absorptive. Since dynamite darkens with age a light-colored stick is indicative of fresh stock, and trade demands, therefore, require the use of a white flour. For this reason it would be practically imposible to introduce the use of a wood flour produced from any colored woods. A good flour should be capable of making a 60 or 70 per cent dynamite (60 or 70 per cent of the total weight being nitroglycerine), without permitting leakage or exudation of nitroglycerine.[2] It is possible to improve the absorptive qualities and power of a flour by mixing it with water, boiling it actively for a short time and then drying, although this process, of course, increases the cost of production appreciably. For dynamite purposes, therefore, wood flour must be as white as possible, it must be absorptive and must be of the proper weight, not only because the size of stick and number of sticks per box is standard, but also because too much flour cannot be used because it would surely disturb the carbon and oxygen balance in the explosive.

In 1900 over 85,846,000 pounds of dynamite were produced in the United States, containing over 9,934,000 pounds of wood flour. In 1909 the production of dynamite increased to about 195,156,000 pounds, although the amount of wood flour used in this dynamite was not stated. The proportion of wood flour used in dynamite in 1909 was probably greater than in 1900 because of a tendency to produce dynamites of a greater strength and the gradual replacement of other absorbents with wood flour. The 1909 consumption of wood flour for dynamite was probably around 20,000,000 pounds. Since 1909 the production of dynamite has no doubt continued to expand and develop as before.

[1]Bureau of Mines, *Bulletin* No. 51, "The Analysis of Black Powder Dynamite," by W. O. Snelling and C. G. Storm.

[2]For pressure and centrifugal tests see page 9, *Bulletin* 51, Bureau of Mines.

LINOLEUM.

In the manufacture of linoleum, wood flour is used exclusively in the production of goods belonging to the inlaid class, either "granulated inlaid" or "straight-line." Cork linoleum is always dark, either the natural brown, or dark red or green. Patterns are printed on cork linoleum, but the pattern soon wears off leaving the dark base. For the production of inlaid goods, in which the pattern goes clear through the piece to the burlap backing, a white base is naturally necessary, not only to furnish a white background where desired but also to permit of dyeing to any color. For this reason a flour as white as possible is desirable.

Linoleum consists of wood flour or cork flour mixed with a cementing material which is spread out on burlap and rolled or pressed hydraulically thereon. The cement consists of oxidized linseed oil melted with rosin and Kauri gum. The cement is the expensive constituent, it being worth from $125.00 to $175.00 per ton, depending on the price of linseed oil. Naturally the lightest flour will produce the largest volume of goods, since the raw materials of linoleum are purchased on a weight basis and sold on a volume basis. The weight per cubic feet is, therefore, along with the color, of prime consideration to the linoleum manufacturer.

The following table shows the comparative weights per cubic foot of cork and wood flours of different sizes:

28 mesh cork	6.25 cu. ft.
56 mesh cork	7.50 cu. ft.
80 mesh wood, imported	13.0 cu. ft.
40 mesh wood, domestic	9.0 cu. ft.

Another manufacturer reports as follows:

26 mesh cork	4 to 4.5 cu. ft.
60 to 80 mesh wood, imported	4.8 cu. ft.
60 to 80 mesh wood, domestic	6.8 cu. ft.

The difference in the above figures is due chiefly to the method of measuring and the amount of tamping in the measure, but in either case the wood flour weighs about 50 per cent to 100 per cent more than the cork. Cork waste before the war was worth about $35.00 per ton and it costs about $5.00 per ton to grind it with power at 1½ cents per kilowatt. Practically all cork flour used in this country is ground here either from domestic waste or waste from Spanish cork mills. Cork flour is, therefore, worth about three times as much as wood flour; but since they both require equal amounts by weight of cement, and since the latter is the expensive item, and also because the volume of goods produced from cork is so much greater than that from wood, the cork linoleum is cheaper for goods of equal thickness than wood flour linoleum. Cork linoleum is also cheaper to manufacture than wood linoleum because it is simply rolled between calender rolls, whereas the production of inlaid linoleum requires a considerable amount of handwork in the production of granulated inlaid and also a tremendous expense for dies in the production of "straight line." The seasoning time for cork is also less than wood flour linoleum of equal thickness. Cork linoleum is slightly more elastic than wood flour linoleum, although wearing qualities are about the same.

MINOR USES.

For composition flooring, plastics, oatmeal paper, etc., the principal requirement is light color, although in some cases certain species are necessary, as in the production of artificial bates for tanneries. The latter consists of a mixture of wood flour, ammonium chloride and certain animal extracts which are absorbed by the wood flour. Here again the trade demands a light-colored product, and it has been found that flour from broad-leaved woods, like poplar, will cause a discoloration on storage, so that only flour from spruce or white pine may be used.

The Nature of Explosives*

General Principles on Which Their Composition and Action Depend

By A. Marshall

It was suggested in the review of Mr. A. Marshall's important work on "Explosives" in *Nature* of June 3, 1915 (vol. xcv., p. 366) that the book would be improved if it had an introductory chapter dealing with the general principles on which the composition and action of explosives depend. Mr. Marshall, writing from Naini Tal, India, says that he had prepared a chapter on the lines suggested for another shorter work of a less technical character than that which was the subject of our review. Unfortunately, through pressure of other work, he has been obliged to postpone for the present the completion of this book, but he sends us the chapter; and we are glad to publish it as a separate article, as the subject is of particular interest at the present time.

Explosions.—When gas or vapor is released so suddenly as to cause a loud noise an explosion is said to occur, as, for instance, the explosion of a steam boiler or a cylinder of compressed gas. Great and increasing use is made of explosive processes in gas, gasoline, and oil engines for driving machinery of all kinds. In these engines the material that explodes is a mixture of air with combustible gas, vapor, or finely-comminuted liquid, and in the explosion these are suddenly converted into water vapor and the oxides of carbon, which latter are gases. Although all these things are liable to explode, none of them are called explosives; this term is confined to liquid and solid substances, which produce much more violent effects than exploding gaseous mixtures, because they occupy much smaller volumes originally.

Explosive.—An explosive is a solid or liquid substance or mixture of substances which is liable, on the application of heat or a blow to a small portion of the mass, to be converted in a very short interval of time into other more stable substances largely or entirely gaseous. A considerable amount of heat is also invariably evolved, and consequently there is a flame.

Gas Evolution.—That evolution of gas (or vapor) is essential in an explosion is rendered evident by considering thermit. This consists of a mixture of a metallic oxide, generally oxide of iron, with aluminum powder. When suitably ignited the aluminum is converted into oxide and the iron or other metal is set free in a very short interval of time with the evolution of an enormous quantity of heat, but there is no explosion. It is indeed because no gas is evolved that thermit can be used, as it is, for local heating and welding.

Heat Liberation.—It is also an essential condition that heat should be evolved in an explosive reaction, otherwise the absorption of energy due to the work done by the explosion would cool the explosive and consequently slow down the reaction until it ceased, unless heat were supplied from without. Ammonium carbonate, for instance, readily decomposes into carbon dioxide, ammonia, and water, but in so doing it absorbs heat; consequently the reaction is much too slow to be explosive. Ammonium nitrate, on the other hand, is decomposed into oxygen, nitrogen, and water, with the evolution of heat, and is consequently liable to explode. A violent impulse is required to start the explosion, but once it is started the energy (or heat) liberated suffices to propagate the explosion, unless the conditions be such that the energy is dissipated more rapidly than it is liberated.

Sensitiveness.—Another essential for an explosive is that the reaction shall not set in until an impulse is applied. If the reaction set in spontaneously, it is obvious that its energy cannot be utilized in the form of an explosion. A mixture of sodium and water evolves hydrogen with the liberation of heat, but reaction sets in immediately the two substances come in contact with one another. Different explosives require impulses of very different strengths to cause them to explode. Some, such as diazobenzene nitrate, are exploded by a slight touch; these explosives are of no practical utility as they are too unsafe. Others, such as fulminate of mercury, are exploded by a moderate blow or a small flame; these are used principally for charging caps and detonators, a small quantity serving to explode a large amount of some other less sensitive explosive. Most of the explosives now used can be exploded by a blow only if it be extremely violent, and many of them cannot be exploded by a flame in the open in ordinary circumstances. The tendency is to use less sensitive explosives because they are safer to handle, but it should never be forgotten that the term "safe," when applied to an explosive, is only a comparative one. The duty of an explosive is to explode, and if it is not treated with proper respect it will, sooner or later, explode at the wrong time with extremely unpleasant results.

Before the subject of explosives was understood so well as it is now, inventors were very liable to think an explosive was very powerful, and therefore valuable merely because it was very sensitive, whereas too great a degree of sensitiveness is really a most objectionable feature. In the middle of the nineteenth century many such mixtures as potassium chlorate and picric acid were proposed through this want of comprehension of a fundamental conditon.

Constituents of Explosives.—The explosive gaseous mixtures used in gas and oil engines to which reference has been made are composed of a combustible material, consisting largely of carbon and hydrogen, and air, the useful constituent of which is oxygen. Similarly, nearly all commercial explosives are composed partly of combustible elements, of which carbon and hydrogen are the most important, and partly of oxygen combined, but not directly with the hydrogen and carbon. On explosion the oxygen combines with the hydrogen to form water, and with the carbon to form carbon monoxide or dioxide, or a mixture of the two. It is the heat set free in this combustion that is the main or entire cause of the rise of temperature. The formation of these two oxides of carbon liberates very different quantities of heat; 12 grams of carbon unite with 16 grams of oxygen to form 28 grams of carbon monoxide with the liberation of 29 large Calories, and the same quantity of carbon unites with 32 grams of oxygen with the liberation of 97 large Calories.

Consequently an explosive is considerably more efficient if it contains sufficient oxygen to oxidize the carbon entirely to dioxide, but the effect is reduced to some extent by the relatively high specific heat of carbon dioxide. In some classes of explosives, however, a very high temperature is objectionable; this is the case with smokeless powders and explosives for use in coal mines. Smokeless powders, therefore, are generally made of such a composition that the greater part of the carbon is oxidized only to monoxide. But there is always some carbon dioxide formed, for it takes up some of the oxygen from the water vapor and liberates hydrogen, or if the total quantity of oxygen be very small there may even be free carbon produced. In the case of safety explosives for coal mines, the temperature of explosion is also sometimes kept low by restricting the proportion of oxygen, but this means is not free from objection because carbon monoxide is poisonous. Other methods are therefore adopted in some safety explosives to reduce the temperature.

Oxygen Carriers.—The oxygen may either be contained in a separate compound, such as saltpeter, which is mixed mechanically with the combustible material, or the two may be combined together in a single compound, as is the case with nitroglycerine, trotyl, and many other modern explosives. The substances rich in oxygen are often referred to as "oxygen carriers"; those most used are nitrates, chlorates, and perchlorates, in which the oxygen is united to nitrogen and chlorine respectively. Ordinary gunpowder, or "black powder," belongs to the class of explosives that have separate oxygen carriers, in this case saltpeter. The table given below shows the properties of the principle oxygen carriers.

It will be seen that the proportion of available oxygen is about the same in the chlorates as in the corresponding nitrates, but whereas the chlorates decompose with the evolution of a small amount of heat, the nitrates require a considerable amount of heat to split them up, except in the case of the ammonium compound. Explosives containing chlorates are consequently much more powerful than those containing nitrates, but they are also very sensitive unless special measures are adopted to render them more inert. The perchlorates require considerably less heat to decompose them than the nitrates, and have more available oxygen. As they are now produced at quite low cost by electrolytic methods, it is not surprising to find that they are being used more and more for the manufacture of explosives. Ammonium nitrate and perchlorate decompose with the evolution of heat, this being due to the formation of water, but the available oxygen is diminished by the same cause. Ammonium nitrate can be detonated by itself, although only with difficulty, and then gives a large volume of gas at a comparatively low temperature. In consequence of this low temperature it has been found very useful as a constituent of safety explosives for use in coal mines, but it also forms part of many other high explosives. Ammonium perchlorate suffers under the disadvantage that amongst its products of explosion is the poisonous gas, hydrogen chloride, or hydrochloric acid.

Potassium permanganate and bichromate have also been used, but they possess no special advantages. Permanganate explosives are often inconveniently sensitive. Attempts have also been made to use liquid oxygen, which has the advantage of being cheap and containing 100 per cent of available oxygen, but the difficulties of employing a liquid which boils at 200 deg. Cent. below the ordinary temperature are so great that these attempts were given up. The Germans are, however, making great efforts to develop these explosives for work in mines, so as to set free a corresponding quantity of nitrates for military use. For the same reason the German authorities are encouraging the use of chlorates and perchlorates.

Combustible Constituents.—In black powder the combustibles are charcoal and sulphur; in blasting explosives many sorts of organic matter have been used or proposed, and some inorganic substances, such as potasium ferrocyanide, ammonium oxalate, and antimony sulphide, but those in common use are not very numerous. For explosives containing nitroglycerin an absorbent material must be used, and of these wood meal is the most usual, but flour and starch are constituents of some nitroglycerin explosives, and in few cases such substances as tan meal and prepared horse-dung are present. Cork charcoal has great absorptive power, but its high cost prevents its use. Ordinary charcoal

Oxygen carrier	Molecular weight	Densit	Reaction	Heat evolved		Oxygen available	
				per mol.	per 100 grams	per 100 grams	per c. c.
Nitrates							
Potassium	101·1	2·08	$2KNO_3=K_2O+N_2+5O$	–75·6	–74·8	39·5	82
Sodium	85·0	2·26	$2NaNO_3=Na_2O+N_2+5O$	–60·5	–71·3	47	106
Calcium	164·1	2·36	$Ca(NO_3)_2=CaO+N_2+5O$	–70·6	–43·0	49	115
Barium	261·5	3·2	$Ba(NO_3)_2=BaO+N_2+5O$	–94·4	–36·1	31	98
Lead	341·1	4·58	$Pb(NO_3)_2=PbO+N_2+5O$	–54·6	–16·5	24	111
Ammonium ...	80·1	1·71	$NH_4NO_2=2H_2O+N_2+O$	+27·6	+34·5	20	34
Chlorates							
Potassium	122·6	2·00	$KClO_3=KCl+3O$	+11·9	+ 9·7	39	78
Sodium	106·5	2·29	$NaClO_2=NaCl+3O$	+13·1	+12·3	45	103
Barium	304·3	3·18	$Ba(ClO_3)=BaCl_2+6O$	+25·9	+ 8·5	31·5	100
Perchlorates							
Potassium	138·6	2·54	$KClO_4=KCl+4O$	– 7·8	– 5·6	46	117
Sodium	122·5	....	$NaClO_4=NaCl+4O$	–12·4	–10·2	52	....
Barium	336·3	....	$Ba(ClO_4)_2=BaCl_2+6O$	– 4·3	+ 1·3	38	....
Ammonium ...	117·5	1·89	$2NH_4ClO_4=2HCl+3H_2O+5O$	+29·5	+25·1	34	65

*From *Nature*.

is a constituent of some explosives, as also is coal-dust. American dynamites often contain resin and sulphur, and those constituents are sometimes met with in other explosives. Oily materials, such as castor oil, vaselin, and paraffin wax, reduce the sensitivenes of an explosive, and one or other of them may usually be found in a chlorate blasting explosive. The addition of aluminium greatly increases the heat of explosion; it is present in the explosives of the ammonal type.

Nitro-aromatic Compounds.—Modern high explosives very frequently contain nitro-derivatives of the aromatic compounds obtained from coal tar, especially the mono- di- and tri-nitro-derivatives of benzine, toluene, and naphthalene. The nitro-groups in these compounds contribute oxygen for the explosive reaction. The trinitro-compounds of substances containing only one benzene ring are explosives in themselves; trinitrotuluene, for instance. Trinitrotuluene is not only a constituent of composite explosives, but is also very largely used by itself as a charge for shell and submarine mines, and for other military and naval purposes, for which its insensitiveness combined with its great violence render it suitable. Picric acid (trinitrophenol) is also much used for these purposes, and trinitrocresol to a less extent. Although they detonate with great violence, these trinitro-compounds do not contain sufficient oxygen to oxidize the whole of the carbon they contain even to the stage of carbon monoxide. Their power as explosives is, therefore, increased by mixing them with oxygen carriers. Commercial explosives containing trinitrotoluene always have also some other constituent which can supply the deficient oxygen.

Nitric Esters.—Nitroglycerin and the nitrocelluloses are the principal members of another very important group of substances that can be used as explosives without admixture. Strictly speaking, they are not nitro-derivatives, but nitric esters. The more highly nitrated celluloses, such as guncotton, contain enough oxygen to convert all the hydrogen into water and the carbon into monoxide, and even some of it into dioxide. Nitroglycerin, $C_3H_5N_3O_9$, not only has enough to oxidize entirely all its hydrogen and carbon, but also has a little oxygen left over. Nitroglycerin is the most powerful explosive compound known, but its power is increased by dissolving in it a small proportion of nitrocellulose, which utilizes the excess of oxygen and at the same time converts it into a gelatinous solid known as blasting gelatin.

Smokeless Powders.—All smokeless powders consist largely of nitrocelulose, which has been more or less gelatinized and converted into a compact colloid by means of a suitable solvent; many of them contain practically nothing else, but in others there is a considerable proportion of nitroglycerin. Small percentages of mineral jelly, inorganic nitrates, and other substances are also added, in many cases to improve the ballistics or the stability. Powders for rifled arms are always colloided as completely as possible, whether they be for small-arms or ordnance, to make them burn slowly and regularly, but in shot-gun powders the original structure of the nitrocellulose is not always destroyed entirely, as they are required to burn comparatively rapidly.

Endothermic Compounds.—There are some explosive compounds which do not depend at all for their action on oxidation or reduction. These are endothermic substances, which decompose with the evolution of gas and heat; they are usually rather sensitive. The only compounds of this class that are of commercial importance are fulminate of mercury, $Hg(CNO)_2$, and lead azide, PbN_6, both of which are used only for exploding other explosives.

Velocity of Explosion.—The heat and gas evolved are the two principal factors which govern the power of an explosive, i. e., the amount of work it can do in the way of displacing objects. But the time taken by the explosion is also a matter of great importance. The rate of explosion is measured by making a column of the explosive, confining it, if necessary, in a metal tube, and measuring the time that the explosive wave takes to travel a known distance. In black powder and similar nitrate mixtures the velocity of explosion is only a few hundred meters a second. This naturally makes them much more violent and destructive. Explosives of the gunpowder type are used when earth or soft rock is to be blasted, or when the material must not be broken up too much. Propellants for use in firearms are required to burn slowly; for rifled arms they must be slower even than gunpowder. They are not exploded by means of another high explosive, but merely lit by a powerful flame, and should then burn by concentric layers. The rate of burning increases with the pressure in the gun, but for completely gelatinized powders it is less than a meter a second.

German Agriculture

An important paper, dealing with the development of German agriculture in recent years, was issued by the Board of Agriculture in the form of a report by Mr. T. H. Middleton, Assistant Secretary to the Board of Agriculture and Fisheries. Accompanying it is a brief prefatory note by the Earl of Selborne, who was then President of the Board of Agriculture, in which his lordship says:

"It has been part of my duty at the Board of Agriculture and Fisheries to make a study of the agriculture of Germany, and in the course of my work it became apparent to me that, if agriculture had made no more progress in Germany than it has in the United Kingdom during the period 1895 to 1915, the German Empire would have been at the end of its food resources long before the end of the second year of the war, and that, as a matter of fact, the war was being fought by it just as much on an agricultural as on a military organization of the nation.

"Accordingly, I asked Mr. T. H. Middleton, C.B., of this department, to prepare a paper showing what had been the development of German agriculture in the last 30 to 40 years and how that development had been accomplished. This admirable memorandum is the result.

LESSONS TO BE LEARNED.

Mr. Middleton deals in considerable detail with agricultural production in Germany during the past 40 years; the main conditions under which German agriculturists and our own farmers work; the organization of German agriculture; and the effects of German economic policy on the progress of German agriculture. In the course of a note on some lessons to be learned from Germany he says:

"1. The German farmer now produces about the same weight of cereals and potatoes per acre as the British farmer; but a much greater weight per 100 acres of cultivated land. The German produces about the same weight of meat and nearly twice as much milk per 100 acres as the British farmer. The German feeds from 70 to 75 persons per 100 acres of cultivated land, the British farmer feeds from 45 to 50.

"2. The ascendancy of the German has been gained in the past 40 years.

"3. The soil and climate of Germany are less favorable to agriculture than those of Britain.

"4. The actual methods of tillage adopted in the growing of corn, potatoes, etc., in Britain are not inferior to the methods adopted in Germany. The difference in production is chiefly due to the circumstance that in Britain more than two-thirds of the cultivated land is now in grass, while in Germany less than one-third of the cultivated land is in grass. There has been a slight decrease in the area annually plowed in Germany; in England and Wales the area which is annually plowed decreased by about 26 per cent in the 40 years before the war.

"5. A comparison of the main features of the agriculture of the two countries is given above. German land is mostly tilled by peasant owners, British land by tenants. The German depends to a great extent on women labor, provided by the families of the occupiers. Wages are relatively low in Germany, and rural industries help to provide Winter employment and tend to cheapen Summer labor.

"6. Much attention has been given to organizing production from German soil. The credit system is well adapted to promote good farming. Co-operation is largely resorted to. Education has been well developed. Societies have been created to provide leadership.

"7. German economic policy in recent years has favored agriculturists, who have benefited partly from the higher prices resulting from tariffs and partly from the steadying effect which the known policy of the state has had upon the industry.

"8. The general effect of the agencies and influences mentioned in the two preceding paragraphs has been to produce a very rapid improvement in the technical methods of the German farmer; the use of manures and feeding stuffs has greatly increased. Superior strains of both plants and animals have been raised. Business methods have been introduced and important rural industries have been developed."

ADVANTAGES OF RESEARCH.

An account of the rapid progress of the German agriculturist, Mr. Middleton states, might perhaps give the impression that he is now much more skilful than the British farmer. This conclusion, it is said, would not be fair to the latter. Though the German peasant is neither scientific in his methods nor teachable, he has more regard for "authority" than the English farmer, and adopts the advice provided for him by chambers of agriculture and societies, and the excellence of the instruction provided at the agricultural colleges has been made possible by the very close attention given by the Germans to research in agriculture. Continuing, Mr. Middleton says:

"When comparison is made between the ordinary methods of farm management adopted in the two countries, there is only one respect in which the British farmer lags behind, and that is in the use of manure. This shortcoming, too, is not so great as the actual figures suggest; it is largely because the British farmer has less tillage land and less sandy soil to manage, that he uses less manure. The present differences between the average British and German farm are not so much differences of quality as of quantity. German crops are certainly no better, German breeds of live stock are certainly not so good as our own; the chief explanation of the greater food production of Germany is that the German is able to till two-thirds of his cultivated land, while the British farmer tills one-third.

"While, therefore, Germany has temporarily gained an ascendancy in food production, because her policy has been to grow food, while ours has been to import it, there is not the slightest reason to suppose that she has natural advantages which we have not; or that, if the people of this country demand the production of more food within the British Isles, the farmer will fail.

" 'SPEED THE PLOW.'

"The clear lesson which we may learn, if we wish to learn, from German experience, is that if we desire to make any considerable addition to our home-grown supplies of food, we must, as a nation, adopt the old farming motto, 'Speed the plow.' "

A further point in connection with the development of the "plow" policy, to which attention is drawn by Mr. Middleton, is that which affects labor. The source of German agricultural labor, he says, is the small holding, and until measures can be devised for greatly increasing the area under holdings of less than a hundred acres in this country we are not likely to breed and maintain in the country a sufficient number of that class of worker which will be required if we are greatly to extend our arable land.

"The main source," he says, "for an increased food supply in Britain, as in Germany, must, however, be the land already being farmed, and provided that enough of this land can be diverted from grass to tillage the pressing problem will be solved."

Summing up his impression, Mr. Middleton's conclusion is:

"From the agricultural policy of Germany we may learn something, and from the admirable machinery—administrative, educational and commercial—set up to lead, teach and finance agriculturists, we may learn much."—*The London Daily Telegraph.*

The Artificial Purification of Oysters

The biologic conditions most favorable for the production of high class oysters are too frequently associated with those which tend to produce pollution. This circumstance has caused disease from the consumption of contaminated oysters. Three radical remedies which have been suggested for this danger are: alteration of sewage disposal outfalls, removal of the beds, and prohibition of the fishing of oysters in polluted areas. In many cases, for economic reasons, none of these remedies are available. It has been found that if contaminated oysters are placed in unpolluted tidal or stream water they will purify themselves in a very short time. In the Summer months, only a few hours are required, and in the hibernating period, a few days. This method has been put into practice in Europe, but two factors militate against its universal application. The people of the United States are accustomed to purchasing oysters of a good quality at a low price. The cost of this operation would be prohibitive. Moreover, it would rarely be possible, in the immediate neighborhood of the oyster beds, to find unpolluted water areas for purification purposes with a saline content similar to that of the waters in which the oysters have been grown. These facts have stimulated the search for other methods of purification. Mr. W. F. Wells, sanitary chemist in the United States Public Health Service, has obtained entirely satisfactory results by the use of small quantities of bleaching powder. He places oysters in basins or floats containing a suitable quantity of water, and then treats them with two doses of a suspension of calcium hypochlorite. The second dose is given after six hours. In each case a quantity of bleaching powder is used which gives 1 part of available chlorin in 4,000,000 parts of water. The experiments are believed to prove that in this simple and inexpensive manner, oysters which have lain in polluted water can be purified to such a degree as to pass the most rigid standard, without in any way interfering with the normal life of the oyster, or producing any appreciable difference in flavor.—*Journal of the Am. Med. Asso.*

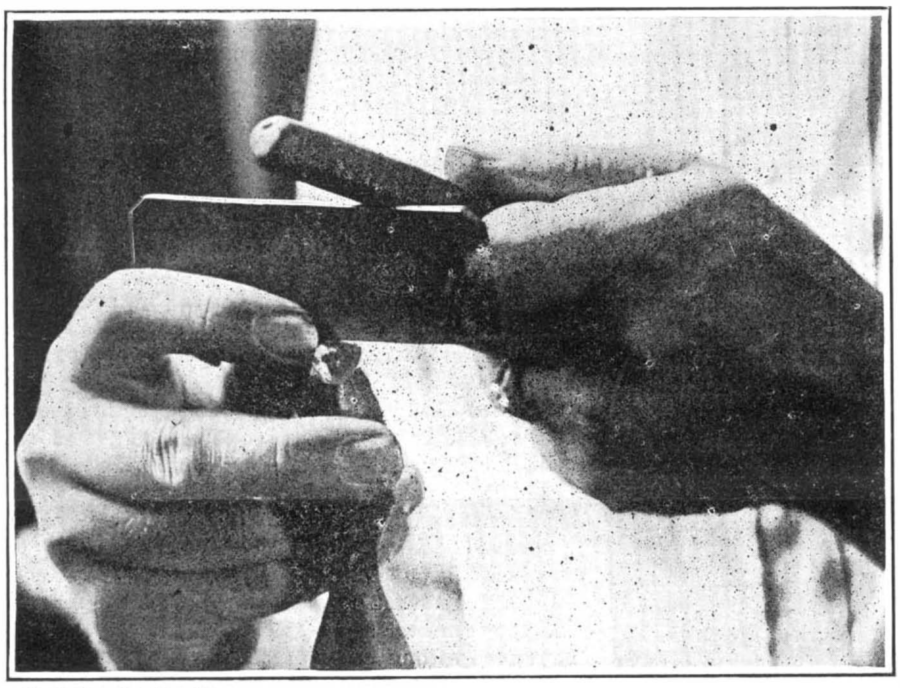


Photo by Pach Photo News, Inc.

Splitting the rough stone with a sharp steel blade.

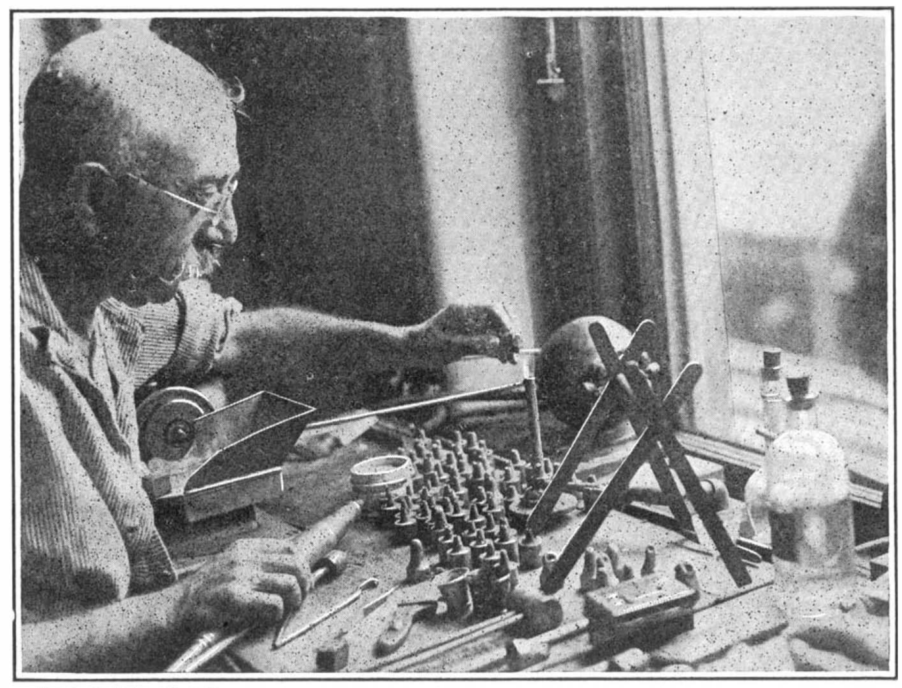


Photo by Pach Photo News, Inc.

Imbedding a diamond in lead in a holder.

Diamond Cutting in America

New York Succeeds Amsterdam As the Gem Market of the World

SINCE the earliest days of the art Amsterdam has had a monopoly of the work of cutting diamonds, and outside of that country few competent workmen could be found, for it is a difficult art to acquire and there has been little exact knowledge of its technicalities outside the shops of Holland, where diamond cutting has been largely an hereditary trade, its secrets and processes being handed down from father to son for many generations. Of late, however, partly owing to the interruptions of the business due to the war, and to some extent because of the rapidly growing sales of precious stones in this country, America has become one of the largest, if not actually the largest, diamond market in the world, and the trade of diamond cutting has become established here on a large scale.

So far the larger part of the diamond cutting that is being done in this country is the work of New York shops, where it is said there are now twenty or more shops, employing over five hundred skilled workmen. Most of these men are Hollanders, who have for several years been drifting over here in increasing numbers because of diminished employment at home and also because of the wages they can command here, which are vastly higher than they ever received at home. As an indication of the magnitude of the business of diamond cutting in this country it is said that approximately $1,000,000 worth of diamonds are cut in New York every month, and these, too, are mostly of the better grade of stones.

For fifty years experiments in diamond cutting have been made at various places in this country, but progress in the business has been slow, for the processes involved require great experience and judgment, and the necessary skill has been difficult to attain, particularly as the expert workmen of the old country have heretofore been disinclined to leave their homes to chance the uncertainties of a trade new to this country. Now the tide has turned, and with rapidly increasing business and the coming of many skilled workmen diamond cutting is firmly established here, and on a scale that promises to make New York the permanent diamond market of the world.

As the diamond comes from the mine it is a rough, whitish stone, and to make it marketable it must be cut to the forms that have been found by experience to be the most suitable to develop its attractive qualities and to give it the finish and polish that best brings out the wonderful sparkle and fire that in all time has been so admired of men and made the diamond the king among precious stones.

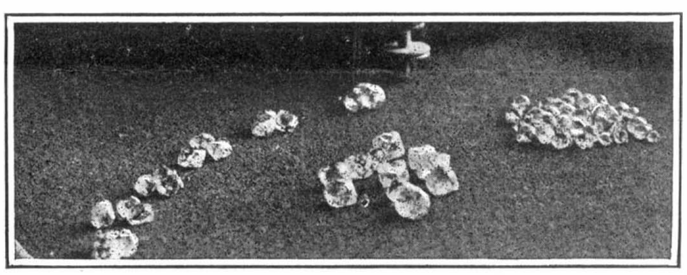


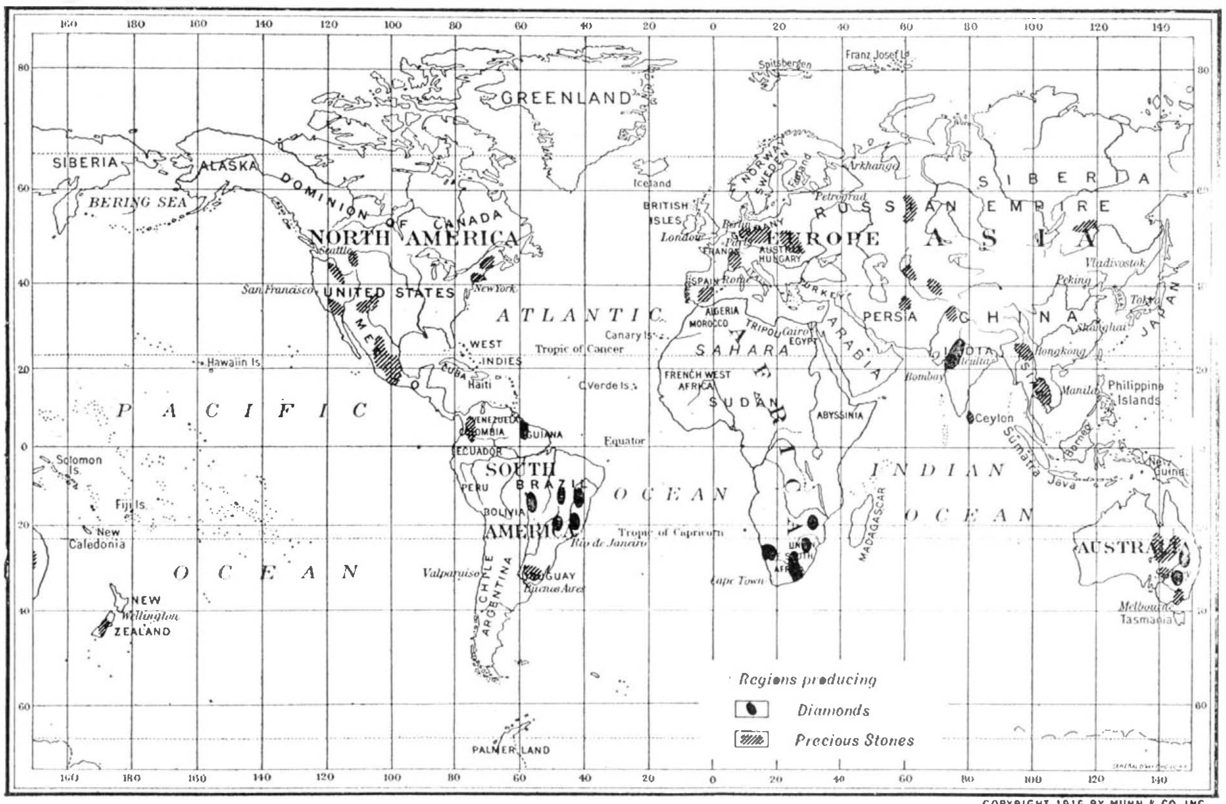
Photo by Pach Photo News, Inc.

$100,000 worth of rough diamonds.

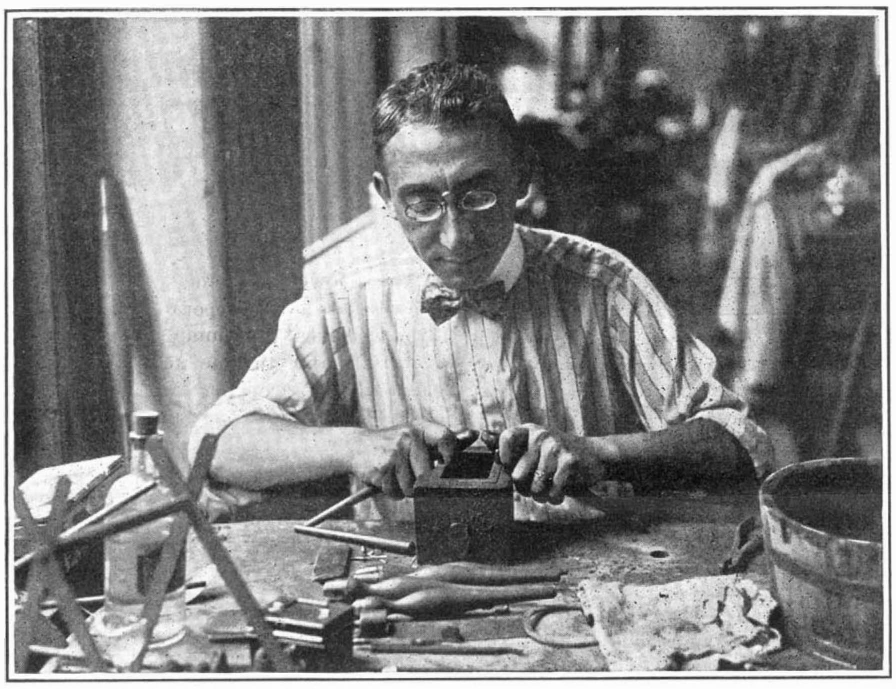
To do this great judgment and long experience is required, for each individual stone must be treated so as to best develop its particular qualities with as little loss as possible, for the diamond is too precious to waste in experiments and a careless or inexperienced workman can easily ruin a stone worth thousands of dollars.

The first process in cutting a diamond is to submit the rough stone to a critical examination to determine to which one of the recognized forms it can be cut with best advantage, taking into consideration both its quality, character and the least waste incurred. This requires great experience and good judgment, for on the decision depends largely the profits of the business. Sometimes a large stone of excellent quality will be found to contain several minute flaws, in which case it may be desirable to split it up into several smaller pieces, to enable the flaws to be eliminated, and it requires an expert to determine how the stone shall be divided to secure the best results. On making his decision, the examiner indicates where the stone is to be cut by little scratches, and it is then passed to the splitter, who divides the stone by sharp blows on a steel blade. This requires much knowledge of the character of the stones, for they can be easily split on the proper cleavage planes, but may easily be crumbled and ruined by the improper application of the tool. This operation of splitting not only divides the stone into the desired parts, but also removes much of the superfluous material, and the parts containing defects; but there is still another shaping process to which the stone must be submitted to quickly bring it approximately to its final form and this is performed by sawing. First the stone is fixed in a holder, by embedding it in a small mass of lead that is carried in the end of the tool. Thus mounted it can be presented to and held against the saw, which is a small disk of phosphor bronze, extremely thin and without teeth, which is revolved at a great speed. The metal itself would make no impression on the hard diamond, but its edge is kept charged with diamond dust mixed with oil and this forms a tooth that very slowly cuts into the stone. It may be said here that every particle of waste material from splitting and sawing of the stones is carefully saved for use in the sawing and other subsequent operations, for the diamond is the only thing that has been found that will cut a diamond, and from this fact comes the well known saying, "Diamond cut diamond."

The operation of sawing



The principle sources of precious stones.



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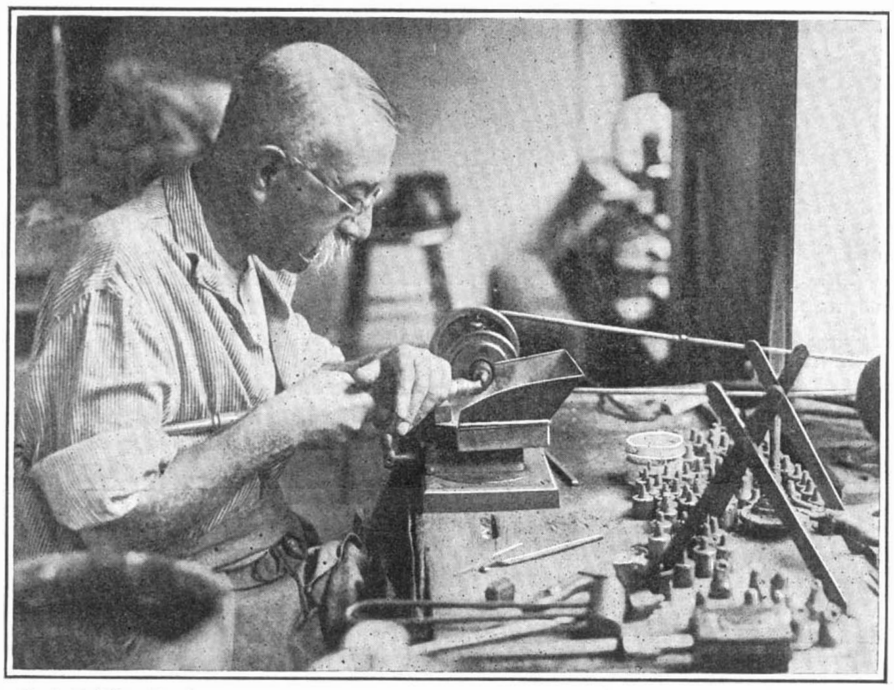
The old method of hand cutting by rubbing one stone against another.



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Shaping the stone by holding it against another revolving stone.

diamonds, although it would seem to be simple, involves a great deal of technical knowledge and is really a trade secret that is carefully guarded to such an extent that it is followed as a separate trade, and some of the large establishments that conduct all of the other operations do not attempt to saw their stones, but send them out to shops that make a specialty of this branch of work.

The sawing reduces the stone only roughly to its final size, and to finish it and produce the many glistening facets, sometimes as many as fifty-eight in a well cut brilliant, it must now be cut and polished. Formerly this was done by mounting two stones in separate holders and patiently rubbing them together, the two faces being smeared with a mixture of oil and diamond powder; but now the work is done on a horizontal wheel of iron that revolves very rapidly, and upon which the stone to be cut is pressed by means of the holder above mentioned. Even with this mechanical aid the process is very slow and requires great patience, and moreover it requires the greatest manual skill, for it is impossible to use any gage or measure for locating and forming the numerous facets, and the cutter must depend entirely on his eye, and a false move would quickly lead to disaster. Like the sawing operation the cutting wheel must be charged with diamond dust, and even then the cutting of a single stone requires the work of several days.

Diamonds are found in many parts of the world, as will be seen by an inspection of the accompanying chart, and they come to the cutter in all shapes and sizes, but it is only on rare occasions when a stone like the historic Kohinoor is found. This great diamond, when it came into the possession of Queen Victoria, weighed $186\frac{1}{16}$ carats (English), but was later recut, reducing its weight by 80 carats. The largest diamond that has yet been found is the Cullinan, which was discovered in the Premier mine in Transvaal in 1907, and weighed 3,025¾ carats (English), or 1⅓ pounds in the rough, and at that it was apparently only a fragment of a larger stone. In cutting this immense gem it was divided into nine large stones and a number of brilliants, the largest finished stone obtained being only 516½ carats (English). The carat, as is well known, is the standard of weight by which diamonds are valued and sold, and this weight, for many years, varied somewhat in different countries. The English carat was equal to 3.17 grains, or 0.2054 gramme, but a few years ago a standard international carat of 200 milligrammes was adopted by most of the principal countries of the world.

In the process of cutting about 60 per cent in weight of the rough stone is lost, and this, added to the cost of cutting and the rarity of these fine gems, partly accounts for the high cost of the finished diamond.

Radium and Aerials

THE following abstract of an article by E. Leimer in the *Elektrotechnische Zeitschrift*, printed recently by the *Electrician*, contains a report of some experiments on new lines.

On the results of Szilard with radium-coated lightning conductors, becoming known to the author he was led to consider the possibility that radium might exert some effect upon the reception of radio-telegraphic signals. The first tentative experiments seemed to give evidence of positive effects; but as the author was obliged to discontinue them in consequence of the war he now publishes his results with a view to stimulating further research and also obtaining independent confirmation of his own conclusions.

Photo by Pach Photo News, Inc.

A diamond polisher and his wheel.

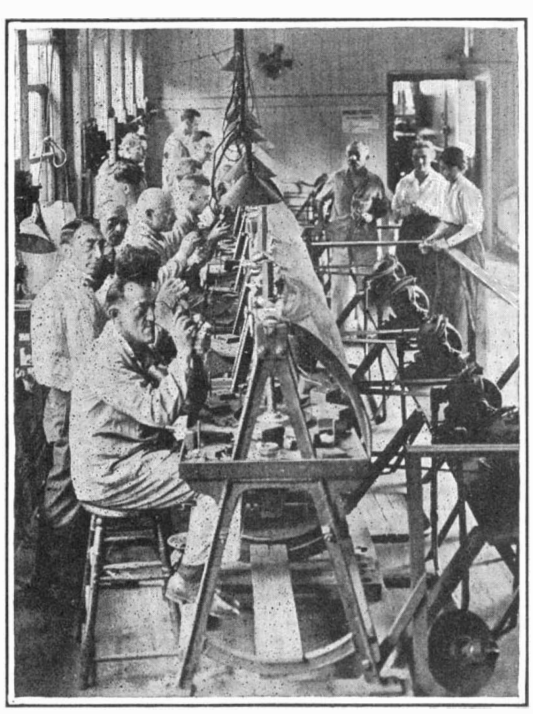

Photo by Pach Photo News, Inc.

A diamond polishing room in New York.

The first experiments were made with an indoor antenna consisting of a wood rod closely wound throughout its length with wire, the rod being directed towards a sending station, FL, about 300 km. distant from it. This antenna was suspended in a room. The receiving set used comprised a galena detector, 4,000 ohm telephones, and a tuning coil 50 mm. in diameter, and having 800 turns of enamelled wire. No signals were audiable from FL at any position on the tuning coil. Signals were, however, at once distinctly audible as soon as a sealed glass tube containing radium bromide of 50,000 units (and thus very weak) was brought near. The signals vanished when the shunt resistance was 220 ohms, using the shunted telephone method. The tuning was not at all sharp, and showed no maximum for any length of included wire between 80 and 120 meters. A change in the position of the radium did not produce any noticeable differences; but the orientation had a marked effect. At angles greater than ± 30 degrees the reception ceased entirely.

Encouraged by these results, the author continued his investigations in order to determine the effect of radium on ordinary antennæ. The antenna consisted of two parallel 1.5 mm. phosphor-bronze wires held 1 meter apart and 8 meters above the ground, directed towards the station FL, as was also the connection to the receiving set. For this latter the same tuning coil was employed; but an electrolytic replaced the galena detector, and in place of the telephones a special moving-coil mirror galvanometer, of 500 ohms resistance and period two seconds, was used. The signals utilized were the 10-second time signals from FL. With the best tuning and 56 meters the telephones gave 80 ohms for silence; the galvanometer showed 20-21 microamperes. With the antenna disconnected the current through the detector was 0.7 micro-ampere. On the radium tube being brought near to the free end of the antenna the galvanometer reading was 50-53 microamperes; to reach this maximum the tuner had to be shifted from 56 to 48 meters. In this position the reception without radium was quite as mistuned as it was in the 56 meters position with radium. When the radium was fastened at the mid-point of the antenna no reception was possible, even with the telephones. With the radium arranged at the connected end of the antenna the current through the detector increased to 35-38 microamperes at the 40-meter tuner position. All the results have been definitely confirmed as a result of numerous control experiments, made under conditions as nearly simliar as possible.

These experiments show that by suitably bringing up radium in proximity to the antenna the vibration image of the latter is changed in the direction of an apparent shortening of the wave; further, that a considerable increase in signal strength, as measured in the detector circuit, is occasioned by the proximity of radium, which must in any case be caused by a higher received primary current.

The proximity of radium to the tuning coil itself has, however, the effect of rendering distinctly worse the previously distinct telephonic reception, without it being possible to discern any definite mistuning, and this applies whether the radium tube be insulated or earthed. On the other hand, the radium tube has no noticeable effect on any of the other parts of the receiving equipment.—*Republished by the Electrician from the Electrotechnische Zeitschrift.*

Propelling Machinery for Ships*

A Consideration of the Principal Types of Machines and Their Applications

By W. J. Drummond

THE questions dealt with in this paper are only such as involve general consideration, and no attempt is made to go into details. When deciding on the type of machinery to be adopted in any ship, the most important general features to be considered are—reliability, economy of fuel, ease of manœuvring, and weight in relation to the power developed, the latter being particularly important in the case of warships.

Too much stress cannot be laid on reliability, for the engines of a ship may have to run, and often do, for 40 to 50 days without a stop, and in many cases the safety of the ship depends entirely on the ability of the engines to do the work required of them in a heavy sea and under circumstances never met with in land practice. In addition to being absolutely reliable, marine engines must be capable of being rapidly and easily reversed, and it is essential for warship work that the power developed can be varied from one-eighth full power to anything up to full power, or vice versa, at very short notice. Mercantile and warship machinery are so essentially different in type that it is difficult in most cases to make any fair comparison between the two. Weight, for example, plays a much more important part in the naval than in the merchant service, and whereas a merchant ship has its designed speed at which she ordinarily steams, a warship seldom steams at full speed, and consequently her machinery has to be reasonably efficient at cruising as well as at high speeds. It is a further advantage in a warship if both engines and boilers may be considerably overloaded for brief periods, for extra speed for a short time may be very valuable, even if obtained at a considerable sacrifice of efficiency. In dealing with marine as compared with land installations, it must be remembered that there is no spare machine to put in circuit in case of a breakdown, and that the powers, in turbine practice at any rate, are very much larger, running in a recent battle cruiser to 120,000 s.h.p.

By far the commonest type of machinery afloat is the 3-crank triple-expansion condensing engine, supplied with steam by cylindrical boilers. There are numerous variations of this arrangement, all made with the object of getting more power out of a given weight of coal, and thereby increasing the steaming radius for a given coal supply, or allowing more space for cargo and passengers, or possibly reducing the size of the ship for the same service.

The marine triple-expansion engine as it exists to-day is the result of years of experience, and is a highly efficient piece of machinery. As representing the highest achievement in this type of machinery, the following comparison, at a speed of 19 knots, between two battleships built for the United States Navy is interesting.

The "Texas," 26,000 tons; 2 4-cylinder triple-expansion engines; 14 Babcock & Wilcox boilers; boiler pressure, 285 pounds per square inch; i.h.p. at 19 knots, 19,600; revolutions, 110; coal per i.h.p. per hour, 1.47 pounds; water per i.h.p. per hour, 13.87 pounds; knots per ton of coal at 19 knots, 1.49.

The "Florida," 21,000 tons; Parsons turbines on 4 shafts; 12 Babcock & Wilcox boilers; boiler pressure, 200 pounds per square inch; s.h.p. at 19 knots, 20,200; revolutions, 290; coal per s.h.p. per hour, 1.72 pounds; water per s.h.p. per hour, 15.23 pounds; knots per ton of coal at 19 knots, 1.24.

It is worth noting that the reciprocating-engined ship is the later and larger vessel, and at 19 knots can steam 6 miles to every 5 of the turbine ship for the same expenditure of coal.

The full speed of the "Texas" is 21 knots, and the "Florida" 22 knots. Of course, these figures represent the high-water mark of warship practice in reciprocating engines, and must not be taken as representing the results obtained with cargo or intermediate passenger vessels, but they afford a good example of what can be done.

An arrangement which is the logical outcome of a desire to use the steam down to as low a pressure as possible deserves notice. It consists of 2 triple-expansion engines which take steam direct from the boilers and exhaust into a low-pressure turbine. The usual arrangement is a 3-shaft one, the reciprocating engines driving the wing shafts, and the turbine the center one. In many cases the turbine receives steam at less than atmospheric pressure, and develops from one-quarter to one-third of the total power. In addition to greater economy than either an all-turbine or an all-reciprocating engined vessel, this arrangement has the advantage over an all-turbine vessel of the astern power being a large percentage of the ahead and of the large slow-running propellers of the reciprocating engines being available for stopping the vessel. When the vessel is under way astern, the turbine revolves in vacuo, the steam from the reciprocating engines being passed straight to the condensers. This arrangement has been used successfully on many of the largest steamers afloat, the 6 largest vessels built in 1914 being so fitted.

*Read before the Institution of Mechanical Engineers—Graduates' Association.

In England, so far as large high-speed vessels of both the naval and mercantile marine are concerned, the turbine coupled direct to the propeller more than holds its own in competition with the reciprocating engine, and efforts are principally devoted to attempts at enabling turbines to be used for cargo and intermediate passenger vessels. To do this successfully the propeller must run at 80 to 200 revolutions, while for maximum efficiency the turbine runs at 2,000 to 3,000 revolutions. Chief among the methods adopted to affect this reduction is the mechanical gearing associated with the name of Parsons in England, and Westinghouse in America.

The Westinghouse arrangement has the disadvantage of being more complicated; to obtain more perfect alignment, the gearing is carried by a floating frame instead of being supported by rigid bearings, as in the Parsons system. In both cases the teeth are helical, closely pitched, and cut by special machines so as to insure absolute uniformity and to reduce the noise. Although originally introduced with the idea of making turbines applicable to slow-speed vessels, mechanical gearing has shown its utility in all types of vessels. As typical of the geared turbine machinery for a large intermediate passenger vessel, the following particulars of the Cunard steamship "Transylvania" may be quoted: 9,500 s.h.p. on 2 shafts; each shaft is driven by 2 turbines: a high and a low pressure, operating through reduction gearing of 12½ to 1; revolutions of propellers at the full speed of 15 knots, 130; steam consumption, 11½ pounds per s.h.p. per hour. An astern turbine is incorporated in the low-pressure turbine casing; the diameter of the gear wheel on the propeller shaft is 10 feet, breadth 5 feet. In several cases direct comparison has been made between ships fitted with reciprocating engines and geared turbines. In England the most noteworthy comparison was that between the single-screw cargo steamers "Cairncross" and "Cairngowan," the former, fitted with geared turbines, and the latter with a triple-expansion engine, the vessels being in other respects identical. The test was very exact; both vessels were docked, coated with the same composition and supplied with coal from the same colliery. They were then run at the same speed on parallel courses for 36 hours, and careful measurement was made of coal and water consumption, etc. The net result of the trial may be expressed by the fact that the "Cairncross" burned 27.8 tons of coal per 24 hours, against the "Cairngowan's" 32.8 tons.

As regards geared turbines in warships, practically no data have been published; several British destroyers and destroyer leaders of the "Aurora" type have been so driven, but for large vessels the 4-shaft direct-drive with Parsons turbines is still the only type of machinery used in England, though the United States are fitting geared turbines in one of their battleships.

One of the objectionable features of the early geared turbines was the noise. By paying great attention to the machining of the teeth this has been largely reduced, but there is still a good deal of vibration and noise in the engine room, a matter of considerable importance in passenger vessels. Due to efficient means of lubrication, the wear on the teeth is negligible; on some gear-turbine ships trouble has been experienced with gasification of the lubricating oil, and in consequence smoking is prohibited in the engine room. The efficiency of the gearing is very high; it averages 98½ per cent, and goes as high as 99 per cent.

The two chief rivals of mechanical gearing as a means of reducing the speed of the turbine to a suitable propeller speed are the Föttinger transformer and an electric drive. The Föttinger transformer has been developed in Germany by the engineer whose name it bears. Briefly, it consists of a high-speed turbo-centrifugal pump and 2 water turbines designed to run in opposite directions and for a lower speed of rotation than that of the pump. These are all incorporated in one casing; the steam turbine drives the pump, the water from which drives either water turbine at will, both being rigidly connected to the propeller shaft. Among the advantages claimed for this arrangement are the following: the astern power is a large percentage of the ahead power, sometimes as high as 90 per cent; no power is wasted in windage of the astern turbines as in direct or geared turbine installations; warming up is simplified, for the turbine can be uncoupled from the propeller shaft by not filling the transformer up with water; the transformer acts as an elastic clutch between the propeller and the engine, so that if by any chance the former strikes wreckage, the shock is not transmitted to the engine; a smaller number of units is necessary for a given horse-power than with geared turbines.

Against these advantages may be set the fact that the efficiency of transmission is low, for it only averages 90 per cent as against 98½ per cent for the mechanical gearing; also, the limit for the ratio of reduction is only about 6 : 1, though it is claimed that, by introducing multiple stage pumps and turbines, a ratio of reduction as high as 30 : 1 could be obtained, associated with only a very small loss of overall efficiency. In connection with this type of reduction gear there are numerous ingenious details: one of these is the arrangement whereby the gear acts as a feed heater, without any sacrifice of efficiency. An interesting combination is being fitted on board one of the German light cruisers; at high speeds the vessel is driven by 2 turbines of 20,000 h.p. each. These turbines have, at the high-pressure end, a Curtis wheel which exhausts into a Parsons drum, and operates the propellers through Föttinger transformers. On the port shaft, abaft the transformer, is a gear wheel which is driven by means of a pinion on the end of a shaft of a 2,500 h.p. cruising turbine. This cruising turbine exhausts into the low-pressure end of the starboard turbine, and turns the port main turbine round in vacuo when the vessel is cruising.

The maximum power the Vulkan Company are willing to guarantee for the transformer is 30,000 h.p. per shaft.

Turning now to the electric drive, this has its chief advocates in the United States, and so great is their faith in its efficiency and reliability that the "California," a battleship, is to have electrical machinery. The decision to fit electrical reduction gear in the "California" was arrived at as a result of the success achieved with the fleet collier "Jupiter"; in this ship the machinery consists of 1 9-stage Curtis turbine driving a 2-pole 3-phase generator, generating current at 2,200 volts; the propellers are each driven by 1 36-pole 3-phase induction motor, so that the ratio of reduction is 18 : 1. The revolutions of the propellers are 110, speed of vessel 14 knots, s.h.p. 7,150; at full speed the steam consumption is 11.2 pounds per s.h.p. per hour. In connection with both the electrical drive and geared turbines, it may be noted that the United States Navy Department built 3 colliers identical in all respects, with the exception of the actual driving machinery. For the driving machinery they fitted an electrical drive in the "Jupiter," geared turbines in the "Neptune," and reciprocating engines in the "Cyclops." The geared turbines in the "Neptune" were fitted with a pneumatic bridge control whereby the turbines were placed under the direct control of the navigating officer; it is contended that this gives much greater rapidity of manœvring than with the usual system of engine-room telegraphs. The results of the numerous trials were not decisive in pointing to any one system as being superior to the other two, and the Navy Department has since built, or is building, 3 battleships each fitted with one of the types of machinery tried on board the colliers. Among the difficulties encountered with such large electrical installations on board ship may be mentioned that of insulation, particularly when water finds its way into the engine room. The increased complication and danger from faulty insulation are the chief objections to the electrical equipment as at present proposed. Of course, it is not necessary to use steam turbines as the prime movers, and suggestions have been put forward in which the engine room is to approximate very closely to Diesel power stations on land, just as many engines being kept running as are necessary to supply current to the main propelling motors. The chief field

in which the electrical reduction gear would be useful appears to lie in the direction of vessels equipped with a considerable amount of machinery other than the propelling machinery, e. g., dredgers of various types and fleet colliers.

It is largely upon the efficient and regular working of the auxiliaries that the main engines are dependent for the good results obtained. It is not easy to single out any one auxiliary for special mention, but of recent years perhaps more attention has been paid to the air pump and condenser than to any other auxiliary. To such a high pitch have these auxiliaries been brought that vacua of within ¾ inch of the barometric height are usual on board turbine vessels. On board reciprocating engined ships such high vacua are not usual, or so necessary from the point of view of economy, for to attempt to make adequate use of such high vacuum the low-pressure cylinders would have to be excessively large.

Boilers on board ship fall into two main divisions—ordinary cylindrical or Scotch boilers, and the numerous types of water-tube boilers; with very few exceptions the distinction is that between mercantile and naval practice. The Scotch boiler, double or single ended, holds its own on merchant ships on account of its cheapness of construction and upkeep, simplicity, reliability and economy in the hands of comparatively unskilled firemen.

From the naval point of view the cylindrical boiler is too heavy, takes up too much room, is not sufficiently adaptable to the rapid variations demanded in the supply of steam, and takes too long to raise steam. With water-tube boilers on turbine-driven destroyers, the time of getting under way, starting from a cold ship, is that necessary to warm the turbines thoroughly, and has been known to be as little as 20 minutes. A few merchant ships are fitted with the Howden system of forced draught, but by far the greater number rely entirely on natural draught; in the Howden system a casing fitted on the front of the boilers is kept supplied with air at a pressure of 2 to 3 inches of water, the air is heated by the funnel gases and then introduced into the furnace through suitable openings. The arrangement for forced draught fitted on warships is more elaborate, and consists in making the whole stokehold airtight and keeping it under a pressure of 1½ inches of water in a battleship, to as high as 6 inches in a destroyer, when running at full speed.

The use of oil fuel on shipboard is limited to warships almost exclusively, in spite of its obvious advantages from an engineering point of view, among which may be mentioned ease of stowage, ease of embarking, high calorific value, wide range of power available at short notice, and the ability to force a vessel as long as the fuel lasts, for the fires do not get choked nor the firemen tired. A recent oil-burning destroyer could be run up from 5 to 25 knots in 2 minutes without any previous warning being given to the engine room. The large coal-burning warships are all fitted to burn oil as well and carry a certain amount of it, up to 1,000 tons. This is to enable them to maintain a high speed for a long time if ever it should be necessary to do so.

The only objections to the general use of oil fuel are the high cost and limited supply.

A type of engine which may make the use of oil fuel more general in the merchant service is the Diesel. A limited number of Diesel engines have been fitted on board ship, but up to the present time they are all of comparatively low power.

In addition to increasing the power of the individual engines, greater reliability, improved methods of reversing and of varying the speed of rotation will have to be provided before the number of Diesel engines afloat can be expected to increase to any extent, except for such specialized work as submarines, where electrical power is available for going astern, and for starting up the Diesel engines. In one or two cases Diesel engines have been fitted as the cruising machinery on oil-fired turbine destroyers, but it will be some time before the Diesel engine can hope to oust steam in such vessels, for the boilers, turbines and all auxiliaries only weigh about 40 pounds per s.h.p., and the oil consumption at full power, about 20,000 s.h.p., is 0.9 pound per s.h.p. per hour.

Catalysis of Hydrogen Peroxide

By Platinum.—Experiments were made with platinum black and spongy platinum, using hydrogen peroxide purified by distillation in a vacuum before use, and having a concentration of 30 vol. The peroxide was heated with the platinum in tubes about 16 mm. in diameter, maintained at a constant temperature in a water-bath, the gas disengaged being collected and measured. The decomposition of the peroxide and liberation of oxygen was regular, and the speed of the reaction increased with the weight of the platinum used and also with the fineness of the state of division of the platinum sponge. An increase in the volume of hydrogen peroxide in relation to the catalytic agent, all other conditions being the same, produced some increase in the volume of gas liberated, but not a proportionate one. This proves that the action of the catalyst is limited to the field immediately around it. The comparison of the activity of platinum black and of spongy platinum in the same state of subdivision, proved that the former was much more energetic in its action, and possessed special properties as a catalyst, due probably to the presence of hydrogen compounds of platinum, since heating to 400 deg.—500 deg. Cent. caused it to lose this superiority over spongy platinum.

Ferric Oxides.—The catalytic action varied greatly according to the physical condition and state of subdivision of the oxide. Ferric oxide freshly precipitated by ammonia and dried, after washing, at 180 deg. Cent. possesses a remarkably rapid catalytic action, which is greater in the cold than at 69.5 deg. Cent. The same oxide, after heating to a red heat, has its efficiency as a catalyst enormously reduced. Colcothar, the brown-red oxide, is a less efficient catalyst than either of the above, the reduction being partly due to its greater density. Its action increased with the weight of oxide employed, but not proportionately.

Aluminum Oxide.—Experiments with alumina freshly precipitated and dried at 120 deg. Cent. proved that the oxide possessed a retarding action on the decomposition of the peroxide, i. e., it is a negative catalyst.

Cerium oxide is a good catalytic agent, its efficiency being no doubt due to its fine state of sub-division. Silica was prepared by decomposing a silicate with hydrochloric acid, and evaporating twice to dryness. The dried oxide proved an efficient catalyst, its activity increasing rapidly with increase of the weight used. Some experiments were also made with this oxide after heating to redness, and this was found to be a more efficient catalytic agent than the dried oxide, the efficiency being rather more than doubled.

Thorium oxide was found to be only a moderately good catalyst; in small quantities it acted as a negative catalyst. Only when the weight of oxide used exceeded 3 grams, with 30 c.c. of 30 vol. peroxide was the decomposition much accelerated.

Experiments With Carbon.—Coconut charcoal is more active as a catalyst than any other form of carbon, though less efficient than spongy platinum. The relative times required for the liberation of the same volume of gas from the peroxide, using one gram of the catalyst in each case, were as follows: Hydrogen peroxide alone, 240 hours; coconut charcoal, 15 hours 4 minutes; wood-charcoal, 212 hours; sugar-carbon, 142 hours. The efficiency of charcoal as a catalyst seems to be measured by its absorptive power for gases, and in many respects catalysis by charcoal resembles that by spongy platinum.

The following general conclusions are drawn from the results of the whole investigation: (1) The temperature required to produce a given rate of decomposition is lower when a catalyst is present; without a catalyst decomposition occurs very slowly. (2) The rate of decomposition increases with the weight of the catalyst, but not proportionately. (3) It also increases with the fineness of subdivision of the catalyst, i. e., with the active surface presented. (4) Diffusion and the mixing of the solution due to the liberation of the gas are the chief agents in renewing the surface of the liquid in contact with the catalyst.

The catalyst studied may be divided into two groups. Those in the first owe their power to the formation of an unstable combination with oxygen; mercury and the iron oxides and possibly platinum black are examples of this class. The other catalysts, e. g., charcoal and spongy platinum, owe their power to the physical property which they possess of absorbing gases in their pores. Their catalytic action is due to the attractive force exercised by the occluded gas upon the oxygen, loosely held in the hydrogen peroxide molecule, and their efficiency is dependent upon the gas surface which the catalyst presents to the liquid by which it is surrounded. The attractive force brought into play is physical and not chemical, since it is independent of the nature of the gas with which the pores of the catalytic agent are charged.—*Abstracts in Jour. of the Soc. of Chem. Ind., from an article by G. Lemoine in Comptes Rendus.*

Coir and Its Preparation

Coir, the fiber from the husk of the coconut, is best (finest, most lustrous, and most resilient) when taken from the immature nuts, eight to ten months old. The practice, however, of using green husks for fiber, would reduce the output of copra, a much more valuable product. Unless extra prime articles are wanted, the husks from ripe nuts are very satisfactory. At present these husks are practically valueless except in places where they are used as fuel. This state of affairs is causing the waste of a commodity which has the world for its market, and a broad field of uses open to its application. The partly-cleaned fiber is excellent for calking boats to prevent the water from entering. The clean fiber is used, without further preparation, for upholstering and for stuffing cushions and mattresses. Mr. Wright, of the Wright Furniture Company, Manila, says that well-cleaned fiber at 6 centavos per kilo could be used by his company in great quantities. When twisted into ropes and cables, coir is used by ships where the waves jerk and pull incessantly and where resiliency as well as strength is needed. Coir is without a peer where sudden heavy strains are placed upon it. Doormats and hall matting of coconut fiber are in demand throughout Christendom.

For rope and mats the fiber should be well cleaned. This may be done in any one of several ways, three of which are worthy of mention here. In most Oriental countries where coir articles are made, the husks undergo a long period of retting. They are buried in pits along the seashore where the constant change of tidal water keeps them wet without permitting decay. The husks are left in these pits for from eight to ten months, causing the corky pulp to soften and disintegrate to such an extent that the fibers may be separated from it and thoroughly cleaned with very little subsequent labor. The retting process is sometimes carried on in vats of fresh water; but this system is very unsatisfactory, since the husk decay, and the fiber becomes weak and of diminished value.

Machines have been tried for cleaning coir, but they have thus far been only a partial success. The husk is soaked to soften the pulp somewhat and is then fed by hand, a small section at a time, to a series of comb-like wheels. As these wheels can shred only one end of a section at a time, the piece must be fed in, withdrawn, reversed, and fed in again, to each of the wheels. These clutch wheels, as they are called, are graded from coarse to fine, as are the cards which follow them for the purpose of further loosening the pulp and combing the fiber. The partly-cleaned fiber is then thrown into a drum, where it is beaten and shaken to remove the dust and impurities, after which it is carded again and is ready for use. Theoretically this is all right; but in practice fibers are broken, and poorly cleaned; and the hand feed makes the process slow.

In the third method the husks, after the outer, glossy part is crushed to admit of the free permeation of water, are soaked for a period of twenty-four hours. (It may be found necessary to place a weight on the husks to keep them covered by the water.) They are then taken out, the glossy part peeled off, and the husk beaten on the concave side with a mallet until the fibers are finely separated and the pulp is thoroughly loosened. Rubbing and shaking before all the pulp is beaten loose only lengthens the process. Beating the convex side of the husk before the fibers are all separated causes the husk to split up into segments instead of being divided into its component fibers by the elimination of the pulp. After the fibers have been separated, the dust is shaken out and the material is ready for washing and picking apart still further, to get rid of the last of the extraneous matter. Drying completes the process.—*Charles F. Fraker, in the Philippine Craftsman.*

Commercial Possibilities in Deer

In a recent issue of the *Zoological Society Bulletin*, published by the New York Zoological Society, there is an excellent article by Dr. Raymond L. Ditmars on "Deer for Parks and Preserves," in which the suggestion is made that there is a possibility well worth the attention of breeders in raising several varieties of deer, both as specimens for exhibition and for their value as venison. For the latter purpose the Indian and Malay Sambars are specially mentioned, and it is stated that in the Southern States conditions are ideal for handling these species. They are a splendid breeding animal, the adults weighing from 500 to 600 pounds, and selling for $150 in New York. The article gives much information relating to deer that is valuable to those interested in these animals.

The Preservation of Sandy Beaches*

Studies Made in the Vicinity of New York

By Elliott J. Dent, M. Am. Soc. C. E.

THE object of this paper is to set before the Society the results of the writer's study of the effect of wave action on the sandy beaches skirting the south shore of Long Island and the New Jersey shore north of Asbury Park, to call attention to the means by which improved beach property may be protected, and to emphasize the damage that must inevitably result to the beaches as a whole if the erection of structures that interfere with littoral drift is allowed to continue.

The paper treats of such subjects, only, as are considered of primary importance in the particular locality under consideration. It is subdivided into sections, and the contents and conclusions are described by sections:

Tidal Currents and Ocean Currents.—These currents are of no effect except in the vicinity of inlets, and receive only brief mention.

Waves.—The behavior of deep-sea and shallow-water waves prior to the plunge receives a brief mention. The phenomena accompanying the plunge, the up-rush and the back-wash of the wave, and the phenomena accompanying the undertow are discussed and illustrated in some detail.

The Origin of Beach Sand and Gravel.—A brief discussion is given, and the conclusion is reached that the principal source of such material is not the grinding up of cliffs, etc., but the sorting out of particular sizes from the soil formed by the decomposition of the primary rocks.

Typical Beach Forms.—Typical beach forms are discussed and illustrated, particular emphasis being placed on the distinction between the temporary berms and the more permanent dunes, etc.

Constructive and Destructive Power of Waves.—The transporting power of the up-rush, back-wash, and undertow are discussed. The conclusions are arrived at that wave action always causes a transfer of material from the beaches to deep water, that in the normal case berms are constructed during stormy weather and eroded by undermining during quiet weather.

Littoral Drift, and Jetties and Groins.—Littoral drift is described, and the effect thereof of inlets, jetties, and groins is discussed. The conclusions are reached that, for beaches such as those under consideration, inlets, jetties, and groins interfere with littoral drift and increase the quantity of material permanently lost to the beaches.

Bulkheads.—The proper functions of bulkheads and sea walls, their proper location with respect to the berms, and the absence of extensive erosion due to back-wash, are discussed. The conclusions are reached that such structures, when their strength is commensurate with their exposure, will afford a real protection to lands in their rear, that their existence will not prevent the formation of berms when other conditions are favorable, that if not placed too far seaward they will not interfere with littoral drift, and that when used to extend the uplands beyond their natural limits such structures may cause a serious loss to the beaches to their leeward.

The increasing value of ocean beach property has led many investors to build nearer and nearer the shore line, relying on the erection of shore-protection works to guard their investments against damage from the sea. Under-estimates of the forces to be resisted and over-estimates of the efficacy of certain types of shore-protection works have resulted in extensive property losses in the immediate vicinity of New York City. In view of the importance of such beach colonies as Coney Island, the Rockaways, and Long Beach, on the south shore of Long Island, and in view of the existence of similar colonies extending in a nearly continuous line along the New Jersey coast from Seabright to beyond Asbury Park, the writer has been tempted to prepare this paper, setting forth such of the general principles of beach formation and erosion as apply to these localities.

The first time he was required to report on plans for the protection of a portion of one of these beaches, he advocated the erection of a system of groins. The direction of the littoral drift was well established, and, in the literature on the subject, no doubt was expressed as to the efficacy of such structures "when properly designed." The case in point appeared to be so simple that the writer had no doubt as to his ability to design the structures properly.

Subsequently, the writer spent much of his time for two summers walking the beaches around New York City. Occasional beach trips were made during the winter, and certain beaches around San Juan, Porto Rico, with which the writer was familiar, were revisited during the summers of 1914 and 1915. At the same time the literature on the subject was quite thoroughly examined. Memoranda made during these visits furnished the foundation of observed facts on which the discussion herein presented has been based.

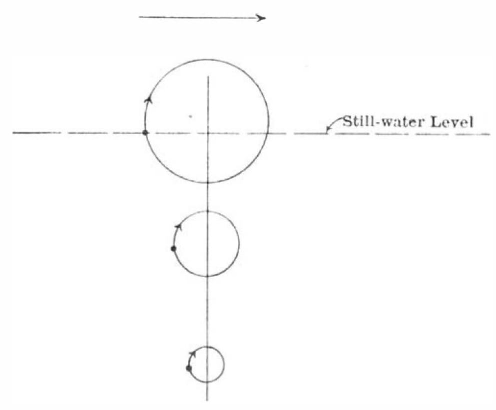

FIG. 1.—As a deep-water wave passes, each particle of water moves in a circular orbit; the radii of the orbits decrease with increased depth below the surface; when the wave has passed, each particle is left in its original position.

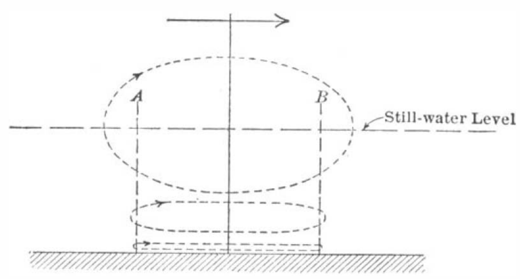

FIG. 2.—In a shallow-water wave, the orbits of the various particles of water are ellipses; the focal length of all orbits is a constant, *A B;* near the bottom the orbits approach a straight line as a limit; the velocities accompanying the forward and backward swings are equal.

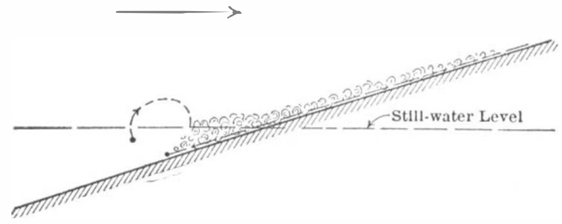

FIG. 3.—When the plunge occurs, orbital motion ceases, and a boiling mass of water rushes up the beach; when the kinetic energy has been entirely dissipated, or transformed, the back-wash begins, and the water flows down the slope in a smooth sheet; the transporting power of the up-rush on the up grade must, for equilibrium, be equal to the Transporting power of the back-wash on the down grade.

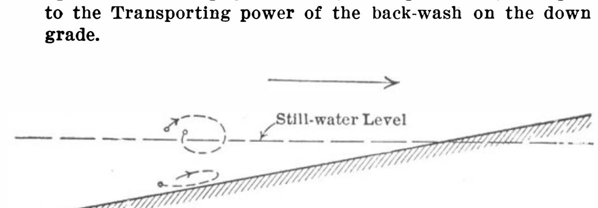

FIG. 4.—Near the shore, as a result of the undertow, the closed orbits are replaced by spirals; near the surface, there is a progressive landward movement, and near the bottom there is a seaward movement.

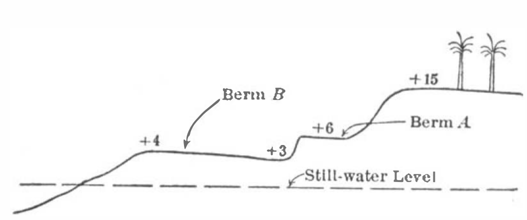

FIG. 5.—Beach at San Juan, Porto Rico, September 19th, 1915. The cocoanut grove stands on semi-permanent sand dunes; berm *A* represents the remains of a much wider berm built up during the preceding winter and eroded back to the scarp during the summer; berm *B* was formed during a storm, about September 15th, 1915.

There are certain general principles of wave and current action that apply to all beaches, but in one instance the controlling force may be very different from that in another. An effort will be made to state quite fully the principles in regard to the major forces at work on the sandy beaches around the entrance to New York Harbor. Some of the forces emphasized in this paper may be of little or no importance in some other particular locality; and phenomena which, in that other locality, may be of controlling importance may be entirely ignored in this paper. As an illustration, it may be stated that the problem of shore protection at the foot of the caving bluffs along the north shore of Long Island is totally different from that to be faced along the sandy beaches of the south shore; the latter is discussed in this paper.

TIDAL CURRENTS.

On an open coast, far away from any inlet, there is a semi-daily landward and a semi-daily seaward current. If the tide is rising at the rate of 1 foot per hour, and if the mean depth is 1 foot at a point 3,600 feet off shore, there will be a shoreward current at that point having a mean velocity of 1 foot per second. As the slope of the foreshore, in the locality under consideration, is much greater than 1 in 3,600, the subject of currents due to the flood and ebb tides may be dismissed except in the vicinity of inlets.

OCEAN CURRENTS.

The Gulf Stream directly east of the mouth of Chesapeake Bay has a surface velocity of about 2½ feet per second. If a steady current of equal velocity flowed along the New Jersey coast, in shallow water, with a loose sandy bottom, we might expect to find sand waves, deep pools, and shallow bars, all subject to frequent changes in position. Such conditions do not exist along the shores under consideration, and, so far as this paper is concerned, no discussion of ocean currents is necessary.

Wave action is an important factor in the construction or destruction of ocean beaches. A few of the general principles will be given here, and the reader may consult the various works on the subject if further information is desired. The writer has followed the paper "Wave Action in Relation to Engineering Structures."[1]

The form of a wave is normally that of a common or prolate cycloid. If we assume several filaments of water, parallel to the direction of travel of the wave, and at certain selected distances below the surface of the water, we shall find that there is no tendency of these filaments to cross as the wave passes by. The passage of a wave does not mix the surface water with the deeper water, or *vice versa.*

In deep water each particle of water coming within the influence of a wave moves in a circular orbit. (Fig. 1.) The orbital velocity is uniform, and in the upper half of the orbit the motion is in the direction of wave travel. When the wave has passed, each particle is left in the position it occupied before the wave arrived. The radii of the orbits decrease with increases of depth below the surface.

In shallow water (Fig. 2) the orbits are elliptical in form. The semi-axes of the orbits decrease with increases in depth below the surface, but the focal distance of all orbits is constant. The horizontal or major semi-axis approaches one half of the focal distance as a limit. The vertical or minor semi-axis approaches zero as a limit. A particle of water very near the bottom moves in what is, to all intents and purposes, a straight line. It is important to note the orbital velocity of such particles.

If a circle is described, concentric with the elliptical orbit, and with a diameter equal to the major axis of the orbit; if a point moves along the circumference of the cycle with a uniform velocity, such that the time required to complete the circle is the same as that required by the particle of water to complete its orbit, then the orbital velocity of the particle of water will be such that it will at all times lie vertically above or below the point on the circumference of the circle.

The orbital velocity of the particle of water is at a maximum as the trough or the crest of the wave passes

*A paper presented before the American Society of Civil Engineers, June 7, 1916, and published in the *Proceedings* of the Society, vol. xlii, p. 625.

[1] By the late Col. D. D. Gaillard, Corps of Engineers, U. S. Army, published as *Professional Paper No. 31,* Corps of Engineers, U. S. Army.

over it. As the trough passes, the orbital motion is opposite in direction to the travel of the wave; as the crest passes, the orbital direction is with the wave travel. The velocities in the direction of wave travel and in the opposite direction are equal.

With a moderately sloping foreshore, deep sea waves approaching the beach are diverted in direction. The tendency is to change direction until the travel is perpendicular to the beach. Waves seldom strike the beaches under consideration at an angle of 45 degrees from the perpendicular, or greater.

Assume for the moment that one is observing the effect of a heavy swell following a storm. In deep water a large rounded wave would be seen, its surface section corresponding approximately to the curve of a prolate cycloid; as the water becomes more shallow, the wave rises higher, becomes more pointed, and the section corresponds more closely to that of a common cycloid. When a certain depth is reached, the wave breaks and the upper point falls over, striking the front slope. Depending on the character of the bottom, the magnitude of the wave, etc., this first break may occur in depths exceeding 20 feet.

After the first break, a new wave is formed and travels shoreward until it in turn breaks when it reaches a certain depth. This process continues until water only a few feet in depth is reached, and then the wave breaks for the last time. (Fig. 3.)

This final break is called the plunge, and the point at which it occurs is called the plunge-point.[2] When the plunge takes place, orbital motion ceases, and a boiling, foaming sheet of water rushes up the beach. This will be referred to as the up-rush. As the wave flows up the beach, the boiling diminishes until a relatively quiet sheet of water has been formed. When the kinetic energy has been entirely wasted, or transformed into potential energy, due to the increase in elevation, the back-wash begins, and the water flows down the slope in a smooth sheet. The velocity during this back-wash constantly increases, and, except for a few feet near the upper margin, the back-wash has, in sand, a considerable transporting power.

On sandy beaches, the height of the wave at the time it reaches the plunge-point is not great. A height of 5 feet is not infrequent, but the writer does not recall having seen breakers as high as 8 feet. The depth of water corresponding to the plunge is seldom more than 3 feet.

An after-effect of the plunge that requires special notice is the undertow. When the back-wash reaches a certain point, normally about the line of the still-water level, a new wave is encountered. The water from the earlier wave must find some escape to sea, and it is a matter of common knowledge that an off-shore current, hugging the bottom, is formed. This current is known as the undertow.

Where the undertow exists, therefore, there must be a new condition of wave action, as shown by Fig. 4. Instead of moving in closed orbits, the particles of water move in spirals. Near the surface there is a progressive movement shoreward, and near the bottom there is a corresponding movement seaward. If, where there is a good surf running, a bather will raise his feet from the bottom and float on the surface, he will almost invariably drift toward the beach. If he is standing on the bottom, the nearly constant pressure of the undertow will frequently outweigh the occasional thrust of the wave and a considerable effort may be necessary to avoid being carried seaward. The undertow normally concentrates into streams of considerable velocity, and in such places the lower spiral of Fig. 4 is replaced by a current of varying velocity, but always flowing seaward.

The foregoing discussion of waves has been somewhat idealized. Waves ordinarily approach the shore from a diagonal direction, and the undertow leaves the beach by a diagonal on the opposite side of the normal. The undertow may concentrate into a stream nearly parallel to the beach and break out to sea at intervals. Such phenomena will be observed by any one making a study of a particular beach, and it will readily be understood that they are modifications of the idealized case.

THE ORIGIN OF BEACH SAND AND GRAVEL.

The grinding away of rocky headlands and the accompanying reduction of ledge rock to gravel and sand is frequently referred to in print. Similarly, the wearing away of boulders as they are carried along by mountain torrents is a constantly recurring theme, attractive to the imagination. If, however, the prosaic engineer will pause for a moment to consider, it will be apparent that these are relatively unimportant sources from which beach sand is derived.

The constant agitation of a gravel beach must inevitably wear away the stones and gradually reduce their size. The rounded form of the pebbles is due to this wearing process. Each pebble is constantly reduced in diameter by the conversion of its outer skin into dust, but, by the time any given quantity of gravel

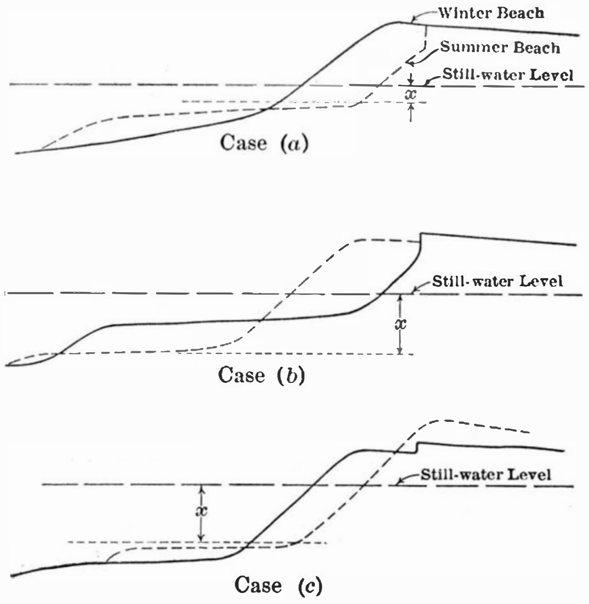

Fig. 6.—The depth of water at the plunge point is indicated by the dimension, x; the form of the beach before it is attacked by waves plunging at the depth, x, is shown by the full line, and the New Form assumed is shown by the broken line.

Case (a) illustrates the erosion of a beach by waves of less magnitude than those by which the beach was built up.

Case (b) illustrates the upbuilding of a berm by heavy waves when the still-water level is at its normal elevation.

Case (c) illustrates the readjustment of the beach formed in case (b) when attacked by waves of the same magnitude as those assumed in case (b), but striking the beach at a time when the still-water level is abnormally raised.

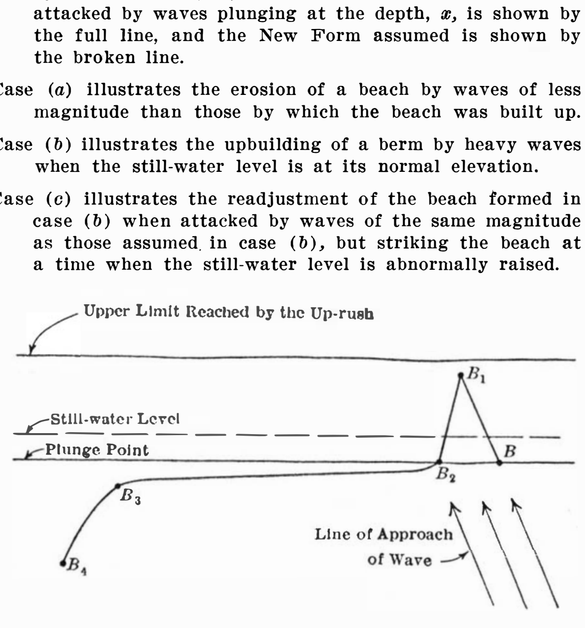

Fig. 7.—Littoral drift is mainly due to up-rush, back-wash, and undertow. A particle of sand at B is disturbed by the plunge and carried by the up-rush to B_1, by the back-wash to B_2 and by the undertow to B_3 and B_4.

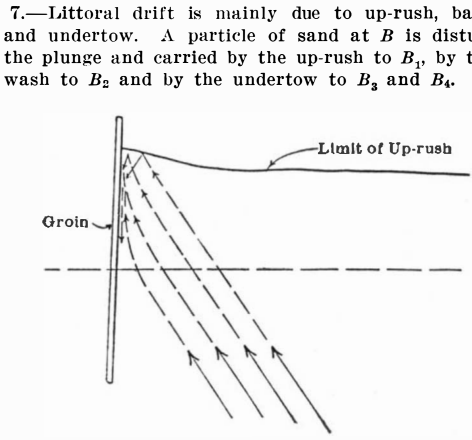

Fig. 8.—A groin inevitably concentrates the up-rush and the back-wash, and drives the littorally drifting sand into deeper water than would be the case on an unobstructed beach.

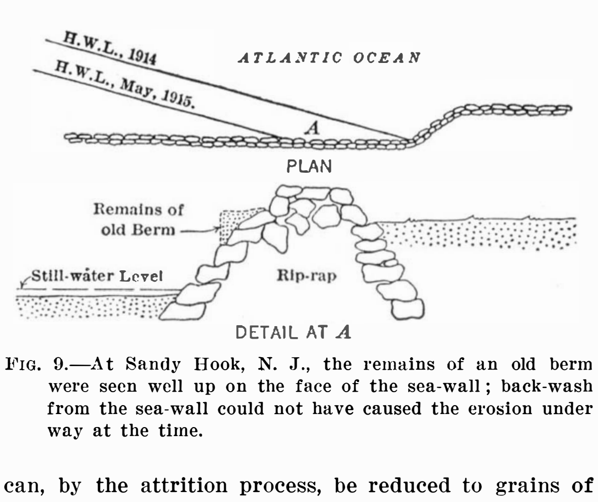

Fig. 9.—At Sandy Hook, N. J., the remains of an old berm were seen well up on the face of the sea-wall; back-wash from the sea-wall could not have caused the erosion under way at the time.

can, by the attrition process, be reduced to grains of sand, there will remain only a small percentage of the original volume.

The principal source of sand in America is the verdure-covered mountain, hill, and valley. Wherever rain falls and vegetation grows the primary rocks are undergoing a process of disintegration. Certain components are carried away in solution, other constituents are transformed into clay, and the quartz crystals remain nearly unchanged. Let some of this decomposed rock, which is called soil, fall into a stream of running water, and the various sizes are quickly sorted out. The clay may be carried to deep water in the ocean without a halt, the finest sand may travel hundreds of miles before it is temporarily deposited, the coarser sand may be deposited within a few miles, and some fragments of rock may be rolled only a few feet during each freshet, and may, in traveling a few miles, be converted into typical rounded pebbles.

The nature of the sand found in most rivers and on most beaches is proof of its origin. It is the friable but insoluble quartz which has survived, and the grains are much more angular in form than pebbles formed by the attrition process. In the immediate vicinity of rocky cliffs, exceptions may be noted, and the writer has seen large areas covered with volcanic sand, but the beaches to which this paper particularly refers are no exceptions to the general rule.

TYPICAL BEACH FORMS.

If all except wave action could be eliminated, the normal form of beach would be a series of berms. Several such berms are sometimes found in the case of gravel beaches. In the case of sand beaches, two berms are often noticeable.

Fig. 5 shows a beach of the general character at San Juan, Porto Rico, as noted on September 19th, 1915. This beach builds up every winter during the stormy season. During the summer or quiet season, it cuts away, the limit of the cutting being indicated by the location of the cocoanut grove. Berm A, at Elevation $+6$, was formed during the winter of 1914-15. By September, 1915, the beach had cut away as far as the scarp which, on September 19th, marked the limit of that berm. During a three-day storm about the middle of September, a new berm, B, was built up in front of Berm A, and at a lower level. The high bank on which the cocoanut grove stands represents a relatively permanent formation; the lower berms are temporary in character.

On September 26th, at a point about one-quarter mile west of that represented by Fig. 5, erosion was under way, and the berm was eroded by the undermining action of waves of less height than those by which it was built. The older and higher berm was formed at the foot of the dunes, which represent relatively permanent formation. Almost identical conditions existed at Long Beach, Long Island, on July 25th, 1915, and at Mattituck, Long Island, where the material was gravel, three berms were formed, but information as to the form of the beach below the low-water line at Mattituck was not as complete as could be desired. In general, there is some depth at which the beach quite suddenly assumes a much flatter slope than it has at and above the level of mean tide. Around New York City, with a mean tidal range of about 4.5 feet, this change appears to come at about the level of mean low water. At San Juan, Porto Rico, where the tidal range is about 1.1 feet, the change of slope is very sharp, and occurs in water from 2 to 3 feet deep. A beach noted by the writer on the Island of St. Thomas was similar to that at San Juan.

CONSTRUCTIVE AND DESTRUCTIVE POWER OF THE WAVES.

Just before the plunge, a wave, by virtue of the orbital velocities of its component parts, possesses a considerable store of energy. After the plunge, this energy is largely dissipated, due to the turbulent flow accompanying the up-rush. To preserve the equilibrium of the beach, the turbulent up-rush must have a sand-carrying capacity on the up-grade equal to that of the back-wash on the down-grade. Shoreward of the plunge-point, the constructive power of the up-rush is greater than the destructive power of the back-wash and undertow. The slope of the beach, taken in connection with the character of the beach material, is an indication of the extent of this difference. It would seem that, seaward of the plunge-point, the destructive agencies are more powerful than the constructive agencies. Referring to Fig. 4, it is seen that, near the bottom, the resultant movement is seaward. Unless the sand can be carried to the top of the wave, there is no force to carry it shoreward. The ultimate effect of wave action, therefore, is a constant transfer of sand from the beach to deeper water in the ocean.

As already stated, there is, in the beaches near New York City, a change in slope near the line of mean low water. Above that line, the slope is the measure of the difference in transporting power, for the particular material under consideration, of the up-rush and the back-wash of the wave. In coarse sand at San Juan and at Seabright, N. J., this slope averages perhaps 1:12; at Long Beach, N. Y., with fine sand, the

[2]The terms "plunge," "up-rush," and "back-wash" are borrowed from "Coast Erosion and Foreshore Protection," by John S. Owens and Gerald O. Case, Assoc. M. Am. Soc. C. E.

slope is perhaps 1:40. For any locality, this slope is nearly constant, regardless of the magnitude of the waves that have created it and regardless of whether it is the result of an addition to, or a denudation of, the beach. Seaward of the foot of this slope, the inclination of the bottom is much less.

An explanation of the observed fact that berms, built up during stormy seasons, are eroded by the less violent wave action of the calmer seasons, and that berms attacked by storm waves may be either built up or eroded according to circumstances, may be obtained from Fig. 6, in which three typical cases are indicated.

Case (*a*) represents conditions such as exist when the winter berms are attacked by the summer waves. The plunge-point is at some depth, x, and this is the point of maximum disturbance. Shoreward of the plunge-point, the waves maintain a nearly fixed slope, as described in a previous paragraph. Seaward of that point, the slope of the bottom is steeper than required for equilibrium. The result is a transfer of sand from the berm to the under-water section, and the summer beach indicated by the broken line is formed.

If now, Case (*b*), waves of greater magnitude attack the summer beach of Case (*a*), the plunge-point, in the average case, will be moved seaward to water of some depth, x. Shoreward of the plunge-point the slope of the beach is flatter than required for equilibrium, and a transfer of sand toward the beach commences. The ultimate result is a new berm such as shown by the broken line. It should also be noted that at the plunge-point there is also a transfer of sand seaward, and as this sand is carried into deeper water than that where it lay in the summer beach, the probability of its eventual return to the beach has been diminished. In other words, though the berm has been rebuilt, a certain quantity of beach material has been wasted in the process.

In Case (*c*) it is assumed that the beach formed under Case (*b*) is, in turn, attacked by waves plunging in water of the same depth as in Case (*b*), but that the attendant circumstances are such that the still-water level has been raised. Under these conditions, the berm will be built to a higher level, but the sand used in this elevating process is taken from the face of the berm itself, and the width of the berm is correspondingly decreased.

Many other conditions might be assumed and discussed, but those chosen will show why the beaches around New York City, throughout the summer, present to the eye of a visitor a scarp indicative of erosion; they will show why, in many cases, if not in the majority, the berm at the beginning of the summer is wider than it was at the close of the preceding summer; they will also show why the maximum damage to beach structures usually occurs during an extraordinarily high tide.

The foregoing refinements might have been omitted, and the writer might have limited himself to a brief statement to the effect that, above a certain hydrographic contour, the waves exercise a powerful scouring effect on the bottom; that the sand composing the bottom is constantly agitated and can find no rest until it has reached deep water, or until it has been cast on the beach above high-water mark; that the greater the magnitude of the waves, the wider the zone of agitation, the higher the beach to which part of the material escapes, and the greater the depth to which other material is carried.

Along the south shore of Long Island, the waves, for the greater part of the year, beat on the shore from a direction slightly east of the normal to the shore line. This shore is protected from the northerly storms, and, if the northerly winds are eliminated, the remaining storms will come mainly from an easterly direction.

When a wave strikes the beach from a diagonal direction (Fig. 7), the up-rush carries sand along with it in a diagonal direction. The back-wash also follows a diagonal course, but on the opposite side of the normal. The undertow frequently concentrates into a stream nearly parallel to the shore line, flowing out to sea at irregular intervals.

With the assumed conditions, a particle of sand disturbed by the plunge at B might be carried up the beach as far as B_1. At B_1, the force of the up-rush having been nearly expended, the particle is dropped until the returning back-wash has acquired sufficient velocity to set it once more in motion. The back-wash carries it as far as B_2, where the undertow takes charge. The latter is assumed to be nearly parallel to the beach as far as B_3. At B_3 the undertow turns seaward, and the particle is carried into deep water.

The course followed by any individual grain of sand is an interrupted one, but, in the normal case, certain particles are at all times following each phase of the route shown in Fig. 7. The majority of the sand grains actually make many journeys up and down the slope, with a progressive movement to leeward, before they are finally taken to deep water by the undertow, or are carried to the semi-permanent uplands above the reach of the waves.

A study of the geology of Long Island indicates that during the glacial epoch enormous quantities of sand and gravel were deposited near the easterly end of the island, in a position where they were subject to wave attack. The prevailing direction of the waves has caused part of this material to be carried along the south shore for a distance of 100 miles, and has built up a nearly continuous beach along that shore.

The foregoing description of littoral drift applies to a continuous beach, and attributes the phenomenon of drift to wave action and undertow. It should be noted that any break in the continuity of the beach eliminates these forces. At such breaks, normally, there are tidal currents of considerable strength to be dealt with. Wave action keeps the bottom more or less agitated, and thereby assists the tidal currents in moving the sands.

It would seem that the question whether litorally drifting sand will be carried across an inlet to the leeward beach, to deep water outside, or into the harbor, is largely a matter of accident. In any event, inlets must result in a waste of beach-forming material, for there are strong tidal currents there which are capable of carrying the material far away from either the windward or the leeward beach.

JETTIES AND GROINS.

As used by the writer, the term "jetty" will refer to structures reaching well out into deep water; the term "groin" will be applied to structures reaching only slightly beyond the low-water line. Wherever there is littoral drift, and jetties have been constructed, beaches have accumulated on the side from which the drift comes. Such is not the case with groins.

Referring to Fig. 7, it is noted that the littoral drift takes place largely below the still-water level. Above that level the sand movement is principally up and down the slope, with only a small component parallel to the shore line. A jetty cuts off the littoral drift, both above and below the still-water level. A groin has little effect on drift due to undertow, and, so far as the drift above still-water level is concerned, a groin is effective for a limited distance only.

One effect of groins deserves serious consideration. Consider a groin so high that no water will over-top it. Such a structure (Fig. 8) will inevitably concentrate both the up-rush and the back-wash of the wave. With a low groin a lesser concentration is effected. It has been the writer's observation that, in the normal case, the berm will be cut back, and a valley will be formed in the vicinity of a groin.

In the vicinity of an inlet, a training dike may be of great value in aiding the formation of a beach, even though it does not reach below the low-water line. At points where channels parallel to the beach (sometimes called swills) are formed, temporary dams across such channels may be of benefit, but, as the channels are transitory, permanent dams are unnecessary.

In order that littorally drifting material may pass a jetty, or a groin, it is necessary for it to travel into deeper water than would be the case on an unobstructed beach, and this deflection reduces the probability of its ever being returned to the beach. For these reasons jetties and groins must inevitably cause a wastage of beach material.

BULKHEADS.

When an engineer is required to build a bridge over a torrential river, he first searches for marks indicating the highest points reached by floods. Using the information thus obtained, he builds to resist the forces that must be encountered. Similarly, when erecting structures along a beach, he should take note of the signs showing what part of the beach is transitory and what part is fairly stable. The level of the cocoanut grove at San Juan, Porto Rico, and of the sand hills at Long Beach, Long Island, previously mentioned, represent formations that have remained in their present location for many years, and, in the ordinary run of events, may be expected to last for many years Who builds in front of these stable formations should build strong.

Confronted by a wide berm, such as that at Long Beach, Long Island, the property owner is tempted to erect some form of bulkhead in advance of the line of dunes. The strength of the bulkhead is proportioned to resist the final attack of the waves after most of their force has been spent in crossing the berm. An unfortunate combination of seasons may entirely remove the protecting berm, as it has been removed in former years, and the bulkhead will then be subjected to forces for which it was not proportioned. The result is that the sea takes back its own.

The effect on the berm and foreshore of such substantial sea-walls as are represented by the rip-rap walls guarding the Edgemere Club, the Manhattan Beach Estates, and the neck of land connecting Sandy Hook with the mainland, and of such substantial bulkheads as guard the tracks of the Central Railroad of New Jersey, from Highland Beach to Seabright, should be considered. It is often stated that such structures cause an erosion of the beaches in front of them. The writer believes that this erosion is much less than is commonly thought. The destruction of the berm is usually brought about by the undermining of the other faces, as indicated in Fig. 6 (*a*), or by a rearrangement of the berm material, to obtain a higher berm of less width, as indicated in Fig. 6 (*c*). In the former case the quantity of material above mean low water is diminished; in the latter case it is increased. In both cases the width of the berm is diminished.

Under certain conditions, the back-wash from a sea-wall may tend to undermine its toe by scouring out the bottom for a few feet in front of the wall, but the writer does not recall seeing a single instance of this kind along the many miles of bulkheads near New York City. To erode a berm like that at Long Beach, forces must work far to seaward and must carry the beach material to deep water, or must, by littoral drift, take it to another part of the beach. A seawall would have no material effect on such forces.

The wall in front of the Manhattan Beach property has stopped the erosion of that property, and there is no evidence that it has caused a deepening of the water in front of the wall. There is at the present time a large shoal between Rockaway Inlet and the Manhattan Beach Estates. That shoal is moving steadily westward, and there is no reason to believe that the existence of the wall would prevent the shoal some day from making a contact with the Manhattan Beach property and forming a beach in front of the wall, should other conditions be favorable to such a movement.

The records show that the beach in front of a considerable portion of the sea-wall at the south end of Sandy Hook builds out and cuts away. The sea-wall limits the extent of the erosion, but does not prevent the formation of a new beach when conditions are favorable for such a growth.

In connection with this Sandy Hook wall, the writer on one occasion noted casually a condition that should have been carefully recorded and photographed. Its significance, however, was not realized until later. From memory, the conditions were about as shown in Fig. 9. The beach had eroded perhaps 200 feet in less than a year. The inspection was made in May, 1915, during calm weather. Well up on the wall were the remains of the old berm, just as they had been left by the caving away of the outer part The corners were sharp, and the caving may have taken place only a few hours before the inspection. It is highly improbable the sand scarp would have stood as it was for more than two or three days, yet the beach had already receded many feet from this particular deposit. The essential facts are that the beach in question was being eroded at a rapid rate by waves that were too small even to splash the old berm. Certainly, back-wash from the wall was not the cause of the erosion, nor was the erosion due to the action of storm waves.

A sea-wall having strength commensurate with its exposure will effectively protect the property in its rear. The location of such a wall, however, should be a matter for serious consideration. If placed so as to include permanently a portion of the temporary berms, the sand thus confined must be deducted from the supply that might otherwise be counted on for the maintenance of the beaches to leeward. The right of a property owner to take permanent possession of beach material temporarily deposited in front of his property may well be questioned. A fair compromise would seem to be that the improvement of the semi-permanent formations be encouraged, and their protection by any means not interfering with the littoral drift be permitted, but that no structures having in view the fixation of the materials composing the temporary berms should be authorized unless the work is on such a scale as to constitute a public improvement, taking care of the beach as a whole.

If used to protect an isolated portion of the waterfront, a bulkhead should be placed at about the line separating the temporary berms from the semi-permanent dunes, or in rear of that line. If the protection of the beach as a whole is undertaken, the bulkhead, seawall, or detached breakwater may be placed so as to include the temporary as well as the more permanent formations.

It should be understood that the construction of a detached breakwater or a sea-wall inclosing the berms will effectually stop the littoral drift along that frontage until a new beach has been formed outside of the sea-

wall or breakwater. If there are beaches to the leeward the effect on them may be disastrous.

Detached breakwaters should afford protection to the beaches in front of which they have been placed. They should create along those beaches conditions similar to those existing in protected bays and harbors. So far as the protected beaches are concerned, rapid changes due to wave action will be done away with, and the beaches may be extended by dredging and filling if desirable.

CONCLUSION.

It would appear that along each mile of open beach there is a constant transfer of sand from the shore to deep water. When littoral drift is the source from which the supply necessary to maintain the beach is obtained, the quantity of material brought to the section must, in order to maintain the beach, be at least equal to the material carried into deep water plus that carried away by littoral drift.

Assuming a section of beach where the littoral drift is exactly sufficient to replace the wastage, no checking of the sand at any point will benefit the beach as a whole. The valuable part of water-front property is the part corresponding to the level of the cocoanut grove in Fig. 5, but the value of this portion is somewhat dependent on the existence of a sufficient berm at a lower level. Uplands may be protected by sea-walls and bulkheads, but bathing beaches must necessarily lie outside of such structures.

The writer knows of no means by which exposed sandy beaches for surf bathing may be preserved except by feeding fresh beach material to them as rapidly as the old material is carried away. The rate of growth of Rockaway Point and Long Beach would indicate that many millions of cubic yards per year are required by the beaches of the south shore of Long Island to counterbalance the demands of the littoral drift. There are no data, so far as the writer is aware, by which the quantity of sand carried annually into deep water can be approximated. At all events, it is safe to say that, if the natural supply of beach maintenance material was to be cut off, any attempt to make up the deficiency by dredging or other artificial means would be a stupendous undertaking.

Along the New Jersey shore north of Asbury Park there remain to-day only a few isolated temporary berms. Along most of that shore the waves are eating into the semi-permanent formations or are battering against the bulkheads. It would seem that the only salvation for many sections of that beach lies in the construction of sea-walls of sufficient strength to combat the waves until such time as new berms are formed, if such time ever comes.

A study of the littoral drift on the south shore of Long Island and the disastrous results to certain beaches that have followed temporary stoppages of that drift would be well worth while. The stoppages in the past have been brought about by natural causes, but the works of Man will play an important part in the future, and we may well take warning while there is yet time and see to it that the interests of the millions who annually visit the beaches of the south shore are properly safeguarded.

The History of Condensed Milk*

With a Note on Its Therapeutical Uses

By Paul Bartholow, M.D.

THE history of condensed milk emerges bit by bit from beneath the records of kindred industries, as, for example, the refining of sugar and the evaporation of fluids and substances liable to decomposition. It deals with important subjects in physics and chemistry which have been stowed away from sight and have therefore been unduly neglected. It is almost essential in understanding the uses of condensed milk that we should know something of the principles upon which it is made, yet this knowledge has hitherto ended at the "curtain" or peroration of the lecturer or manufacturer when introducing condensed milk as a food for children and babies. The mere mechanics of the subject should preserve us from a view so superficial.

Some of the contributions to this science do not demand much notice. The dissertation of Braun, and the brief history of Hosford in the *Milch. Zeitung* several decades ago, come to nothing, or next to nothing, for they describe methods of manufacture that have long since gone to pieces. Mohan, indeed, has given us something more in a brief reference to the patents of Newton and of Green, but it is not clear whether he has read the original specifications or not. For, as to Green's patent, it cannot be stretched to cover any method related to the manufacture of condensed milk.

The invention of the process really originated with Howard, whose vacuum pan recalls some names illustrious in science and trade. It was invented, wrote Maumené in his "Fabrication du sacre," t. i., 3, in 1816. The account of the apparatus was given by Howard's friend, Thomas Thomson, in the *Annals of Philosophy*, 1816, Vol. 8, p. 209, which was translated and published in the *Annales de chimie et de physique*, 1816, p. 373. "In the ordinary way of boiling sugar, the temperature is so high that a considerable portion of the sugar is converted into treacle. Mr. Howard's vessels are globular, and of copper, and connected with an air pump, which is wrought during the whole time the boiling goes on. The consequence is that a vacuum is formed within the boilers. This enables the boiling to take place at a temperature so low that there is no risk of destroying any of the sugar. The vacuum is such as to support a column of mercury from 1 to 4 inches in height. There is a thermometer attached to each boiler, and likewise a mercurial gage to give the degree of rarefaction." (From "A Short Sketch of Mr. Howard's New Process of Refining Sugar.") Manufacturers of sugar and of condensed milk have made full use of this invention. The vacuum pan described in Thomson's memoir is virtually the same as the globular and cylindrical apparatus in use to-day. According to Foster ("Treatment of Evaporation") "the vacuum pan is quite as old, even older than the multiple apparatus . . . it has the same unpractical globular form, low and confined evaporation space, small heating surface."

These passages describe the vacuum pan used in refining sugar and condensing milk; they show that the two industries are inseparably connected. Even the multiple system of Wellner-Jelinek, by which large surfaces of milk or sugar are exposed to evaporation, is used by some manufacturers, in making evaporated milk, which in this context must not be confounded with condensed milk. It is certainly important that Howard's vacuum pan has given such an impulse to the manufacture of condensed milk.

What must be regarded as the most valuable feature of Howard's system is generally found in the manufacture to-day. In nearly all factories the vacuum pans are worked upon the general principle of Howard's. The air is kept, by the working of an air pump, at such a state of rarefaction that the milk boils at a temperature too low to cause browning, and the other changes incident to exposure to a temperature of 100 deg. Cent. By carefully regulating the supply of heat to the pan, and of cold water to the condenser, the progress of the operation being watched through a glass plate in the roof of the chamber, the condensation is carried on at a rapid but uniform rate until completed. The milk after sugar is added is raised to such a temperature that it may begin to boil immediately when brought into the rarefied atmosphere of the vacuum pan.

Richmond in his "Dairy Chemistry" refers to the multiple evaporation system, without, however, telling us where it is employed. A vacuum pan with a fairly large vapor space is used by the best manufacturers in America. The heat is carefully regulated, as well as the cold water to the condenser, and the milk is boiled at an even, rapid rate until concentration is sufficient, a point easily told by an experienced operator. The pans have a large heating surface, fitted with coils, as in the Wellner-Jelinek system. There is a high vapor space and low boiling level, unlike many pans in which the steam coils occupy most of the space, leaving little or no room for the charge. In a really good and modern pan the full charge is only 0.1 to 0.12 meters above the top row of tubes, which are copper. These tubes are placed in 2, 3 or 4 rows, according to the size of the pan, and heated separately with steam. A high vapor space in the pan is indispensable to the manufacture of a good brand of condensed milk, since it allows the dispersion of gases from the mass of boiling milk. Such a system, however, is in my experience not often seen, the proof being the low standard of condensed in the constituents of the original milk. According to Tibbles, these variations in the composition of condensed milk are so great that it is essential that some standard should be fixed. Now, a medium quality of cow's milk would contain before condensation 3.3 per cent of fat, and condensed to one-third its bulk 10 per cent of fat. Such milk should also contain 8.5 per cent of solids-not-fat before evaporation, and the condensed substance at least 25 per cent of solids-not-fat. It has therefore been an established custom of the British Government to stipulate that it should contain not less than 10 per cent of fat and 25 per cent of solids-not-fat. The Board of Agriculture made the following regulation under Section 4 of the Food and Drugs Act, 1899:

"That any condensed milk (other than that labeled 'Skimmed Milk' in conformity with provisions of Section 2, Food and Drugs Act, 1899) in which the amount of milk-fat is less than 10 per cent, or the amount of solids-not-fat is less than 25 per cent shall be deemed to be so deficient in some of the normal constituents of milk as to raise a presumption until the contrary is proved, that it is not genuine."

This English rule is a good one and should be followed.

It is now more than 50 years since Gail Borden first manufactured condensed milk on a commercial scale. In 1856 he received a patent for a "process for concentrating sweet milk by evaporation in vacuo, having no sugar or other foreign matter mixed with it." Readers of advertisements naturally conclude that he invented condensed milk; at least that is the impression these advertisements make until corrected. But there is no doubt in the minds of those who have studied the history of condensed milk in detail that it was a Frenchman who first thought of it, and an Englishman named Newton who perfected it. The Frenchman was Appert, who in 1809 published his "L'art de conserver toutes les substances animales et végétales." This little book, which is now extremely rare, was dedicated to Gay-Lussac. At the time Gay-Lussac was a member of the Board of Arts and Manufactures. His opinion of Appert's method is of particular interest. "The Board of Arts and Manufactures," he wrote, "has reported to me the examination it has made of your process for the preservation of fruits, vegetables, meat, soup, milk, etc., and from that report no doubt can be entertained of the success of such a process. As the preservation of animal and vegetable substances may be of the utmost utility in sea voyages, in hospitals and domestic economy, I deem your discovery worthy of an especial mark of the good will of the government."

Appert tells us how he condensed milk, "reducing it to two-thirds of its original volume." He sweetened it with sugar, though sugar, he says, is "hurtful to the patient." Evidently he disliked sugar. Indeed, his opinion on its use for preserving milk might have been written at the present day. I quote it at length: "A second inconvenience is this, that a large quantity (of sugar) is required to preserve a small quantity of milk; and hence the use of it is not only very costly, but even in many cases pernicious."

It is clear that the original idea in condensing milk was to preserve it, and its appropriate uses are equally distinct. Preserved or condensed milk was intended for armies, fleets and hospitals and not at all for children or babies. An English translation of Appert's work was published in London in 1811. Englishmen followed Appert in his process, and a patent for evaporating milk in a vacuum pan, it is stated vaguely by Mohan, was granted to Green in 1813. I have been unable to find this patent in the Specifications of British Patents. But there is a patent that was granted to Green in 1850 for the "preservation of substances liable to decomposition and destructive agencies." (Eng. Pat. 13,420.)

There is no doubt, however, that the process of condensing milk in vacuo was fully developed in 1835 in the patent granted to Newton. (Eng. Pat. 6,787, 11 March.) As the words of the specification tell the story of the original condensed milk, it is worth while to repeat them. (Specifications of British Patents, 1830-1835.) "A method for preparing animal milk and bringing it into such a state as shall allow of its being pre-

*From the *Medical Record*.

served for any length of time with its nutritive properties and capable of being transported to any climate for domestic or medicinal use."

"Taking the milk in a fresh state, as drawn from the animal, having first strained it, if necessary, to get rid of any dirt or other improper matter which may have accidentally fallen into the pail or other vessel while milking, I introduce into the milk a small quantity of pulverized loaf sugar, say, from fiftieth to one hundredth part in weight of the whole quantity of the milk, which quantity may, however, be greater, dependent upon the desired sweetness of the preparation when completed. On the sugar becoming perfectly dissolved I subject the milk to a tolerably rapid evaporation, either by blowing through the milk warm or cold air by means of a suitable apparatus of any convenient form such, for instance, as those at present in use for evaporating syrups, or by means of external heat in connection with a vacuum above the surface. . . . Warmth will best be obtained from hot water or from steam, or heated air. . . . By evaporating the aqueous particles of the milk in this way, its nutritive or essential parts may be concentrated, and its substance reduced to the consistency of cream, honey, or soft paste, or even into dry cakes or powder, and may in the latter states be exposed to the air for a length of time without being impaired, the sugar tending to preserve it. By dissolving the milk so prepared in a proportionate quantity of warm or cold water the original milk is reproduced, with all its properties."

These early methods of making condensed milk proved most expensive undertakings. Though the quality of the produce was good, even superior, the quantity was clearly not great enough for the needs of fleets, armies and hospitals. It is, therefore, no small achievement of Gail Borden to have manufactured condensed milk on a scale meeting commercial conditions and requirements. I am inclined to think that the article he produced in 1857 was of better quality than the present brands. In 1857 a committee of the New York Academy of Medicine published a report on condensed milk after a visit to Gail Borden's laboratory. The details are not complete, but enough is said to make a not unpleasant picture.

In the following words we get the impression of a primitive process, but one which is not tainted by modern arts. "The milk, immediately after leaving the cow, was strained into an ordinary milk can, then placed in a cold water bath until it was entirely deprived of its animal heat. It was then heated to a temperature of 175 deg. Fahr. The milk is now passed through a second strainer, and without delay removed to a vacuum pan, where water is evaporated. This pan consists of a large metallic vessel supplied with a jacket for the reception of steam, by means of which heat is applied." It is not stated whether sugar was added. The uses of this condensed milk are appropriately noted. It "imparts a delicious flavor to coffee, and whenever used in the various departments of the culinary art has given entire satisfaction." At the end of the report the committee publishes letters from the stewards of steamship companies praising the milk as an article of food on long voyages.

The indications for the use of condensed milk are plain. It is both a food and medicine: a medicine for invalids, the sick in hospitals; a food for soldiers, sailors and travelers. Its chief fault is the seductive sweetness that makes such an appeal to children. Again, the saturation of low-graded milk in sugar is a source of profit to manufacturers. At present the conditions of trade are such as to make the original uses of condensed milk more significant than ever. The food crises in Europe have reached such an acute stage as to necessitate the constant production of condensed milk for the armies and adult civil population.

BIBLIOGRAPHY.

1. Maumené: Fabrication du Sucre.
2. Wing: Milk and Its Products.
3. Tibbles: Foods.
4. Willoughby: Milk: Its Production and Uses.
5. Braun: Ueber kondensierte Milch.
6. Hosford: Milch-Zeitung 1877-8.
7. Mohan: *Journ. Soc. Chem. Ind.*, 1915.
8. Crato: Kondensierte Milch aus mager Milch. Veröffentl. aus d. Gebiete d. Militär Sanitätswesen, Bd. 55.
9. Richmond: Dairy Chemistry.
10. Carrick. The Menace of Skimmed Condensed Milks.

The Propagation of Sound By the Atmosphere

SINCE the beginning of the war the sound of gunfiring in Flanders and France has often been heard in the southeastern counties of England. There can be little doubt as to the origin of the sounds, for the reports of distant heavy guns have a character which is readily recognized. A correspondent of the *Daily Mail* (July 6) states that at Framfield (near Uckfield), in Sussex, it is easy to identify the particular kind of gun which is being used. The great distance to which the sound-waves are carried under favorable conditions is evident from the letters recently published in the *Daily Mail*. As firing has occurred lately over a great part of the western front, the exact position of the source of the sound is uncertain. But if it were in the neighborhood of Albert the waves must have traveled about 118 miles to Framfield, 150 miles to Sidcup, and 158 miles to Dorking.

Of far greater interest are the form and discontinuity of the sound-area. A remarkable example of the inaudibility of neighboring reports in the face of a gentle wind was given in the last number of *Nature* (p. 385). This is a subject on which many observations have been made since the beginning of the present century, especially in connection with the sounds of volcanic and other explosions. The source of sound is always surrounded by an area of regular or irregular shape within which the sound is everywhere heard, though the source is not always situated symmetrically with reference to the boundary of the area. On several occasions a second sound-area has been mapped, separated from the former by a "silent region" in which no sound is heard. Sometimes this second area partly surrounds the other, sometimes it consists only of isolated patches. As a rule, according to Dr. E. van Everdingen, who has made a detailed study of the subject,[1] the least distance of the second area from the source is much more than 100 km., and the intensity of the sound at this least distance is not less than near the boundary of the inner sound-area.

Dr. van Everdingen refers to several dynamite and volcanic explosions which have been carefully studied from 1903 to 1911. He also adds some interesting observations made chiefly in Holland during the present war. The most important case is that of the bombardment of Antwerp on October 8, 1914. The reports were heard at many places in Holland within 100 km. from the source and again outside a circle of 158 km. radius, but at very few intermediate places. The silent region is bounded by two curves, which are roughly circular, the inner arc being traced for more than 180 degrees and the outer for more than 90 degrees. In some cases of heavy firing at later dates there are also indications of silent regions; in others an increased audibility has been established near the line of 160 km. In no case is there any certain indication of any asymmetrical propagation of the sound.[2]

Dr. van Everdingen examines the two explanations which have been offered of the existence of the silent region, one of which relies on variations of wind-velocity and temperature with the altitude; the other (von dem Borne's) on changes in the composition of the atmosphere at great heights. On the former explanation we might expect asymmetry, on the latter symmetry, with regard to the source of sound. He considers that both explanations are true and should be applied in combination. In favor of the second explanation, he urges the facts that in recent cases the outer margin of the silent region has always been about 160 km. from the probable source of sound and that no appreciable deviations from the circular form have been observed. The above distance is greater than the limiting distance (114 km.) assigned by von dem Borne, but Dr. van Everdingen shows that it agrees well with estimates made on the supposition that the percentage of hydrogen in the upper atmosphere is much smaller than that assumed by von dem Borne.

There can be no doubt as to the value and interest of Dr. van Everdingen's investigations. It would seem desirable, however, to continue and extend them. Though the existence of silent regions may be regarded as established, many more negative records are required to prove the symmetry of the region with reference to the source of sound. It must be remembered that the deep sounds of these explosions may at great distances be below the lower limit of audibility of some observers. Moreover, the mean radius of the outer margin of the silent region is very far from being constant. In one of the earliest cases in which the silent region was noticed—that of the minute-guns fired during the funeral procession of Queen Victoria on February 1, 1901 (*Knowledge*, vol. xxiv., 1901, pp. 124-5)—the radius was about 80 km.—*C. Davison in Nature.*

[1] "The Propagation of Sound in the Atmosphere." *Koninklijke Akad., van Wetenschappen te Amsterdam,* Proc., vol. xviii, 1915, pp. 933-960.

[2] It may be mentioned that, on October 28, 1914, the sound of the British naval guns that bombarded the Flemish coast was heard at a distance of 280 kilometers, or 174 miles.

An Advertising Toy

A EUROPEAN patent relates to a toy which serves for advertising purposes, in the shape of a transparent ball of some size made of celluloid and containing a separate piece on the inside for the advertisement. Such piece can be made in most varied shapes and is of flat cardboard or any other suitable makeup so as to fit within the ball and remain in position. The ball itself is made in two halves and put together. The advertising piece can consist of a large star with printing upon it, or again as a representation of any objects such as a hat, pair of gloves, etc. As the ball is transparent, the advertisement portion is clearly visible.

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