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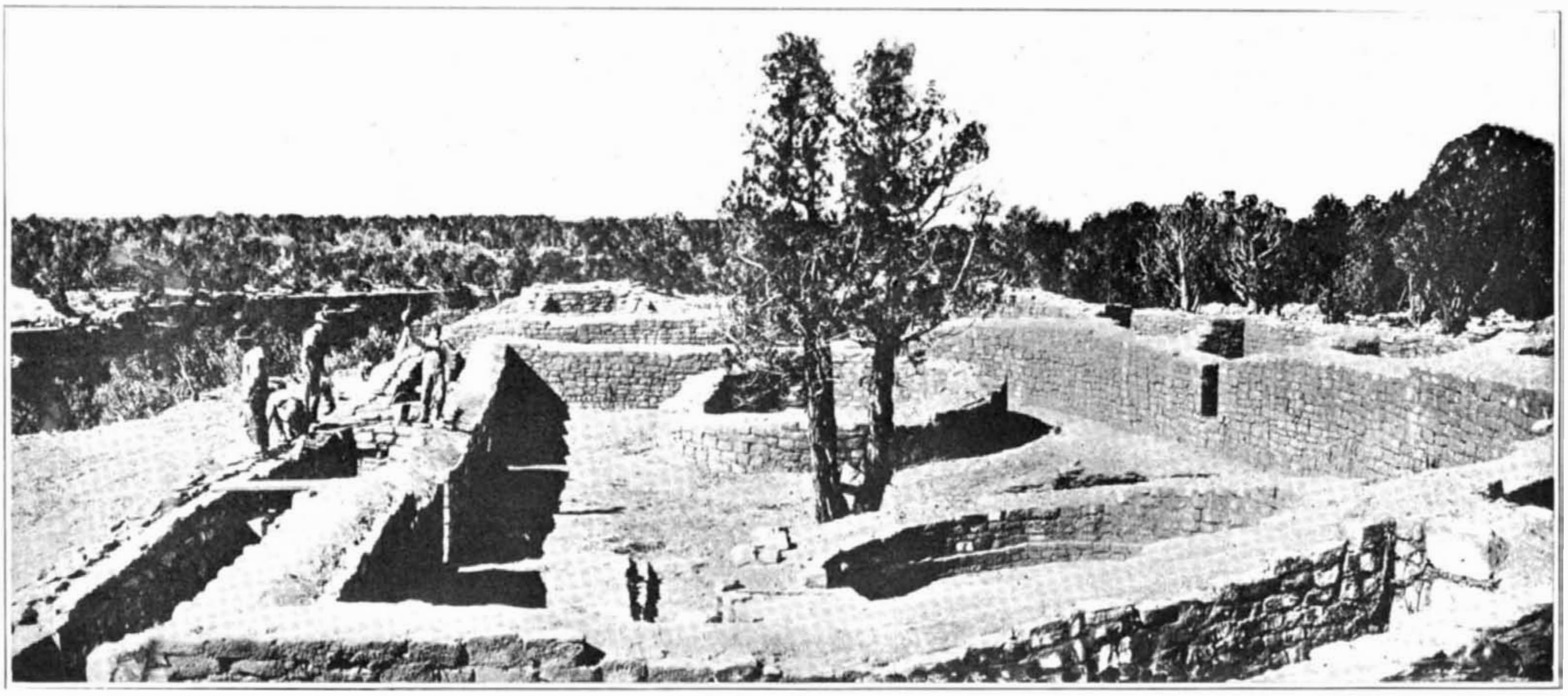
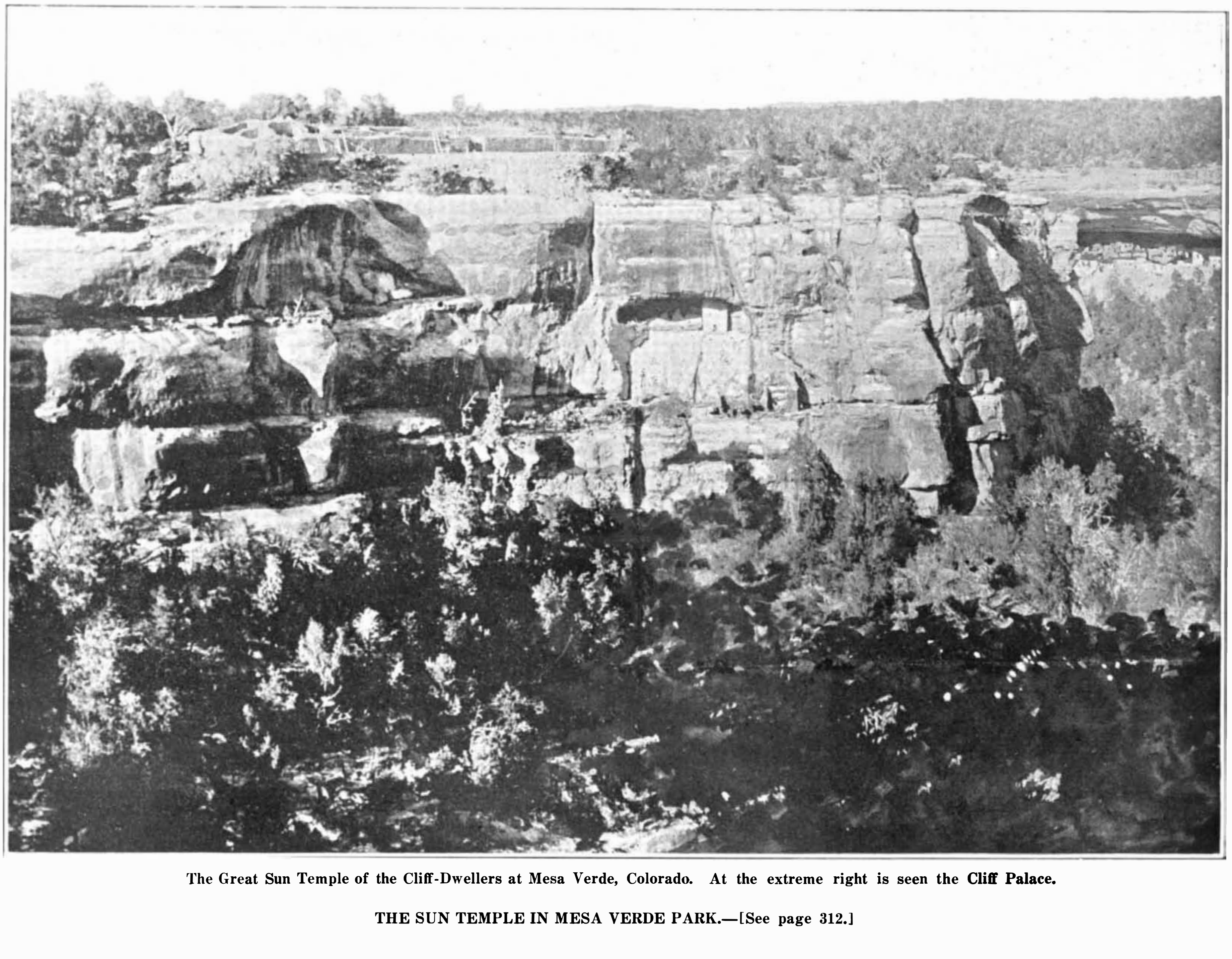


Looking west over the partially repaired ruins of the "Sun Temple," Mesa Verde National Park.



The Great Sun Temple of the Cliff-Dwellers at Mesa Verde, Colorado. At the extreme right is seen the **Cliff Palace.**

THE SUN TEMPLE IN MESA VERDE PARK.—[See page 312.]

Radiations From Atoms and Electrons—II*

A Study of the Character of the Mechanism Within the Atom

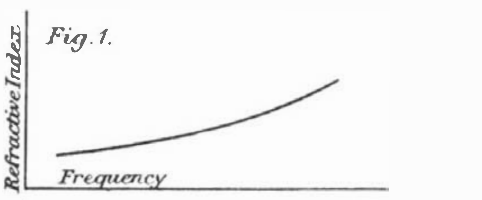
By Sir J. J. Thomson

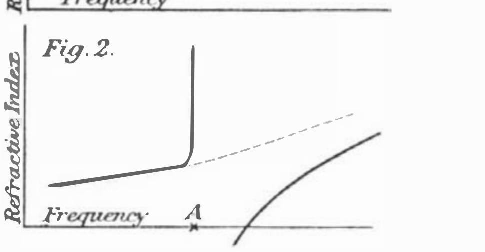
Continued from Scientific American Supplement No. 2105, Page 291, May 6, 1916

In opening the second lecture of his course on the above subject at the Royal Institution, Sir J. J. Thomson, O.M., P.R.S., said that on the last occasion he had discussed the interpretation to be placed on the fact that Michelson had obtained interference between two rays of light, when the difference in the length of the paths traversed exceeded half a million wave-lengths. Such a result would be impossible unless there were a very great regularity in the wave-train. If the latter had been subjected to changes either in amplitude or phase, interference would have been impossible. He had, moreover, raised the question whether it were possible for the mercury atom to persist in uniform vibration long enough to furnish a uniform train of 540,000 vibrations. Had the train passed through a long series of glass prisms, the necessary regularity in the train of waves would have been secured even had the source been intermittent, because the regularities observed in light dispersed through glass were a question of the length of the path, and not of the character of the source.

In the case of the mercury vapor examined by Michelson, however, the length of the wave-path through glass was quite insufficient to produce the results observed, which could not, in short, be accounted for by dispersion of the ordinary kind. Nevertheless, there were reasons for believing that, after all, the remarkable regularity of Michelson's wave-train was not to be attributed to a regularity in the radiating atoms of mercury, but to the influence of the medium by which they were surrounded. In fact, the mercury atoms, active at any instant, were surrounded by mercury vapor, and if this vapor had a very intense dispersive power for mercury light, the effect in question might be due to its action, and not to the character of the actual vibrators. In fact, the principles on which dispersion depended gave reason for concluding that if a mercury arc were in the presence of a substance having an inordinate dispersive power, even a thin layer might be capable of producing the regularity observed.

The usual relationship between the refractive index and the frequency of light vibration was that the higher the frequency the more refrangible the light. Plotting the refractive index for glass against the frequency, yielded in fact a quite common-place curve, having the general form indicated in Fig. 1. With some substances,



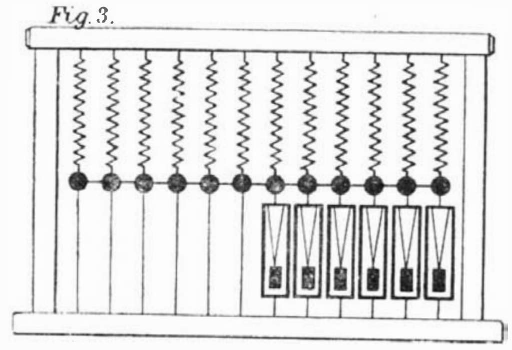


however, an entirely different type of curve was obtained, and such bodies were said to show anomalous dispersion, and all of these bodies were capable of giving out on their own account a definite kind of light. Suppose, in Fig. 2, that *A* represented the frequency of this light that they were capable of emitting. If the curve corresponding to Fig. 1 were drawn for a substance of this kind, it had the character indicated in Fig. 2. At the outset it resembled Fig. 1, but as the point *A* was approached the refractive index shot up as indicated, and theoretically became infinite at this point. Since the velocity of propagation was inversely proportional to the refractive index, this velocity became zero at *A*.

Proceeding to a little higher frequency, the square of the refractive index became negative, and none of this light could accordingly get through the medium. At still higher frequencies, however, light began to pass, and the curve continued as indicated in the figure. In the neighborhood of *A* there was practically infinite dispersion, so that it was quite possible for a thin layer to produce the same effect on light of this wave-length as would a great length of path through glass.

*From *Engineering*.

To illustrate the character of the phenomena involved, the lecturer used a model represented diagrammatically in Fig. 3, with which he was able to show the transmission of waves of different frequencies through a system having a natural frequency of its own. The model consisted of a series of balls hung from springs, and joined by a horizontal wire, as indicated. On the one side there were balls only, but on the other each ball was secured to a frame, in which was mounted a heavy



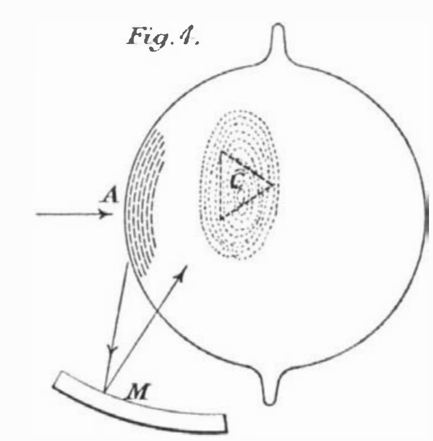
pendulum, and all these pendulums had the same definite time of swing.

In a first experiment with this model, the ball on the extreme left was swung backward and forward at a much lower frequency than the natural frequency of the pendulums. The result was that a wave-motion was established along the horizontal wire connecting ball with ball. This wave, passing through the series of single isolated balls, was continued through those associated with the pendulums, and attention was drawn to the fact that the wave-length in this portion of the system was much less than it was in the section containing the isolated balls, which latter might be taken as representing the free ether. Since the wave-length was less in the pendulum portion, the velocity of propagation was also less there. On increasing the frequency of the disturbance, the wave-length in the pendulum section still further diminished and the velocity of propagation here became very small. In these experiments, the lecturer pointed out that the ball and the associated pendulum both moved together in the same direction. The frequency of the oscillation was next increased to a little beyond that corresponding to the natural time of swing of the pendulums. In this case, although the first unit of the series of bals with pendulums swung violently, the disturbance did not pass through the remainder of the series, but was reflected back along the series of isolated balls. This condition of total reflection, the lecturer pointed out, lasted over a considerable range of frequencies, but finally a point was reached at which the wave passed once more through the series of balls associated with pendulums. At this stage, however, the wave-length was longer in the pendulum than in the rest of the system, and in place of the balls and pendulum bobs swinging together they swung in opposite directions.

This model afforded an illustration of the passage of a wave through a refracting medium, having atoms with a definite period of vibration in their system. It indicated that with such systems a point was reached at which extraordinarily small differences in the frequency made enormous changes in the rate of propagation of the wave. Thus in the case of light in the neighborhood of a point of anomalous dispersion, a 1 per cent difference in the frequency might alter the velocity of propagation 10 to 12 times. At this stage we got resonance between the atoms and the incident light. He dared not put the model shown into exact resonance, as it would all be shaken to pieces; but the effects of resonance could be shown with a simpler model. This model consisted of a spring, one end of which was fixed to the top of a vertical standard, and the other to a cross-head reciprocated by a crank. A weight was secured to the spring at mid-length. This weighted spring had, the lecturer stated, a natural frequency of its own, in which it would vibrate if disturbed. On setting the crank into slow rotation, he showed that the weight moved up and down in time with the cross-head, making "forced vibrations" of a frequency fixed by the rate of revolution of the crank. On setting the latter rotating at a high speed, forced vibrations were again produced; but although the frequency was still the same as that of the cross-head, the direction of motion was reversed, the weight moving up as the cross-head moved down. Finally, when the latter was reciprocated at a rate equal to the natural frequency of the weighted spring, resonance effects ensued, the weight jumping about in the most violent way possible. On this condition of resonance the weight absorbed energy from the crank, while in making its forced vibrations there was no absorption of energy.

This experiment illustrated how in the transmission of light there might be almost complete dispersion for one particular wave-length. An experiment by Prof. R. W. Wood, of Baltimore, had a still closer bearing on an application of the theory which he wished to make. Prof. Wood had shown that when light was passed through a vessel containing a trace of iodine vapor, but otherwise vacuous, a fog appeared in the path of the beam. This fog arose because the iodine vapor was violently excited by light of particular wave-length, and gave out light on its own account. That this was the case could be shown by putting different colored screens in the path of the beam. In some cases the fog disappeared, while with others it remained practically unaffected. In a still more striking experiment, also due to Prof. Wood, the iodine was replaced by sodium vapor.

In repeating this experiment, the lecturer focused, on a bulb containing sodium vapor, the light from the salted flame of a Méker burner. He showed that in the region at which the light impinged there was intense reflection from the sodium vapor, and behind this reflecting layer there was a region distinguished by a faint glow. Professor Wood had, he said, modified this experiment, using the apparatus indicated diagrammatically in Fig. 4. The bulb shown was filled with sodium vapor at a pressure of less than 1/1000 mm. of mercury. Light impinged on the bulb from the left, as indicated, and was reflected at *A* from the vapor inside the bulb. This impinging light was, however, not quite homogeneous, but the reflected light was sent back into of the mirror *M* this reflected light was sent back into the bulb, where it produced the glow indicated at *C*. At this point in the bulb Professor Wood fixed a small triangle of magnesium oxide, as indicated by the dotted lines. This oxide reflected light as perfectly as white paper but the reflecting power of the sodium vapor



surrounding it was so great that its surface could not be seen, its two inclined edges alone being visible.

This experiment showed that for light of the particular wave-length concerned, the reflecting power of sodium vapor under a pressure of less than, 1/1000 mm. of mercury was as great as that of white paper. In making this experiment it was necessary to get the wave-length exactly right, or there would be practically no reflection from the sodium vapor; but if the critical wave-length were correctly hit off, the reflecting power was altogether anomalous, and the little triangle disappeared in the fog thereby produced.

He would apply these considerations to Michelson's experiment in which interference was obtained with wave-paths differing by 540,000 wave-lengths. Suppose, for example, that each mercury vibrator made only a few oscillations, thus giving rise to a certain disturbance. Any such disturbance could, by Fourier's theorem, be analyzed into component harmonics or waves, each of which would spread out with its appropriate velocity. For the mercury atom the velocity of propagation for mercury light was practically zero, so that all the other Fourier components of the disturbance would move

away, leaving that clear which corresponded to the vibrator of the mercury atom. It would thus be seen that the train of waves in Michelson's experiment might have been separated from the other components of the disturbance by the action of the mercury vapor around the luminous centers.

It was accordingly not possible from the data thus acquired to come to any conclusion as to the duration of the regular vibrations of the original luminous source. For this object it was necessary to go to work in a different way.

If a vibrating system did not vibrate for a long period, its effect could not be represented by a simple train of waves. The only disturbance which could not be resolved into a series of simpler component waves by Fourier's theorem was an indefinitely long train of simple waves, regular in amplitude and phase, and such a disturbance was the only known form of simple light. To a train 1000 wave-lengths long, of say sodium light, it would be necesary, in representing it by Fourier's series, to add other wave-lengths, to make up for the fact that the train had a beginning and an end, and these components would show in the spectrum, so that other lines would appear as well as the sodium light. The distance of these lines from the true line would depend on the length of the original train. If the latter comprised 1000 vibrations. the satellites would be close to the original line; while with a train of ten wave-lengths only they would be far away from it. The thickness of a spectral line afforded accordingly one way of estimating the regularity of the original disturbance. Roughly speaking, the most important of the Fourier components (which had to be put in to represent the fact that the wave train had ends) had wave-lengths, which were equivalent to the loss or gain of one, two, or three vibrations during the time that the original excitation lasted. These gave the most important of the satellites to the original line. Hence, if the original train consisted of 1000 wave-lengths, a gain of one wave-length would give a satellite within 1 part in 100,000 of the original line. If the original train were still longer, the satellites would be nearer still. The satellites therefore widened the original line, and did so the more when widely separated than when close to it. Hence, from the widths of the spectral lines it was possible to find the number of vibrations made with undisturbed amplitude in the train of waves received. The results of such measurements indicated that in ordinary spectroscopic observations the train received and recorded as a line must have consisted of at least 100,000 waves, but this did not necessarily imply that the actual source had maintained its vibrations unaltered for a corresponding time.

A good idea of the fineness of the spectral lines was afforded by Lord Rayleigh's demonstration that the actual breadths as observed would be adequately explained by the Doppler effect, according to which a luminous center approaching the observer would indicate to him a wave-length shorter than if it were receding from him. The ratio of the mean velocity of the luminous particles to the velocity of light was about the same as the ratio of the velocity of sound to that of light, and this motion of the atom was found to be of itself sufficient to explain the actual breadth of the spectral lines.

The lecturer referred back here to Wood's experiment in which monochromatic light was caused to pass through a bulb containing a trace of iodine vapor. If a regular train of waves fell on the iodine molecules, and if these molecules were subject themselves to any kind of interior disturbance, other lines besides that due to the incident light might be produced. This might have something to do with some remarkable phenomena described by Professor R. W. Wood, who had found in the spectrum of the iodine light produced in his bulb lines of a previously unknown character. Submitting the iodine vapor to light of a particular wave-length, Wood found that the spectrum showed one set of bright lines, while on using another kind of exciting light a quite different series of bright lines was observed. This effect might be produced by an irregularity in the motion of the iodine, although the light incident on it was itself quite regular. So long as the iodine particle was vibrating in unison with the incident light there was no disturbance and no energy was consumed; but if the iodine were disturbed in any way, then the incident energy would go into establishing free vibrations of the iodine system, and there would be absorption of the light. The effect observed could be explained if it were supposed that motion of the iodine particles was subject to interruptions—such, for example, as arose from the mutual collisions of the molecules, though these could not really be the determining cause in the phenomena under discussion. In such case the energy of the incident light would go into a shaking up of the iodine molecules.

The main point involved was that there was no absorption so long as the iodine was in phase with the incident light and that absorption would only arise when there were irregularities innate in the body through which the light passed. If such irregularities were present, we would get, in addition to the line due to the exciting light, a series of other lines having definite relations to the original line, giving satellites on each side of it, which would diminish in intensity the father their distance out from the parent lines, and this distance out would be greater the more rapid the frequency of the internal irregularities producing them.

Some action of this kind might account for the observations made by Professor Wood. The cause could not. however, lie in the molecular collisions, as the results were independent of the pressure of the vapor. They must thus be due to something inside the iodine atom itself, in which there might be a periodic disturbance which superimposed itself on the exciting light.

To illustrate this point the lecturer made use of a heavy cross-bar suspended from a long helical spring. As is well known, when a helical spring is either compressed or extended, one end of it generally rotates a little with reference to the other. On pulling down the cross-bar and releasing it, the lecturer showed that the ensuing up-and-down oscillations gradually diminished, the energy passing into torsional oscillations, which a little later on were converted back again into vertical oscillations, and so on. The original up-and-down motion of the spring was, the speaker said, to be regarded as equivalent to the effects of the exciting light when no satellites were produced. The energy of this gradually passed into another form, and we had a periodic flow analogous to that between the energy of the torsional and vertical vibrations shown by the model.

If anything of this kind took place in the iodine atom, we should get superimposed on the regular line, due to the incident light, a series of satellites on each side. He would not go so far as to say that this was actually the explanation of the phenomena in question, but it did indicate that it might be quite possible to get a very complicated spectrum from the incidence of a particular line. He had, in fact, only introduced this matter to emphasize the principle that complicated spectra resulting from single lines were due to irregularities in the medium through which the light passed.

There was considerable evidence that the explanation of the absorption of light was to be looked for in some action of the kind described. In the text-books the matter was commonly dismissed by summarily asserting an analogy between the absorption of light and the phenomenon of resonance in the case of sound. Tuning-forks did, indeed, absorb energy from sound-waves of their own periodicity; but this fact explained nothing in conection with the absorption of light. All the time the tuning-forks were absorbing energy they were also giving out similar energy. To explain the absorption of light a conversion of the incident energy into some other form was necessary. The matter was not one of mere resonance, and opacity could be measured by the frequency with which the corresponding interruptions occurred. If they only occurred at long intervals of time, the body was transparent. The absorption of light was thus due to interruptions in the vibration of the atoms of the medium through which the light passed. In fact, it was only when there was considerable regularity in the train of the waves and in the vibrations of the atoms in the path of the light that the light escaped absorption.

(To be continued.)

Correlations of the Magnetic and Mechanical Properties of Steel

The experimental evidence seems to point to the conclusion that there is one and only one set of mechanical characteristics corresponding to a given set of magnetic characteristics, and conversely there is one and only one set of magnetic characteristics corresponding to a given set of mechanical characteristics.

Although there is no evidence to refute the preceding rather broad statement, the utility of this generalization is decidedly limited by the complexity of the relations sufficient quantitative data. Quantitative data, however, are gradually being obtained by the author and due to the large number of variables and the lack of others who are working on this problem. The application of the magnetic tests is further limited by practical difficulties in testing irregular shapes. Even with these limitations, magnetic testing in conjunction with mechanical testing may be expected to be of considerable value in determining mechanical properties.

It has been shown that magnetic observations taken during the course of a tensile test indicate the time when the true elastic limit, the yield point, the necking down point, and the ultimate strength are reached. In addition, the magnetic data give some idea of the uniformity of the material.

If it is once determined what treatment is requisite for a given steel, a magnetic test may be used to determine whether or not the material has been brought into the desired condition.

It is quite possible that the magnetic data may be used to define a bar of steel. In no other manner than by a magnetic examination is it possible without doing violence to the specimens to determine whether two steel bars are identical in properties.

A determination of the magnetic uniformity of a piece of steel may be used as an index of the mechanical homogeneity.

A magnetic test indicates the character of the entire cross section of the metal, rather than merely a surface phenomenon, as in the case of certain hardness tests.

Notwithstanding the possibilities of the magnetic test, it must be remembered that at present they are possibilities only. Before the magnetic characteristics can be of much practical importance a great deal of investigation is necessary and a large number of accurate measurements on specimens of known chemical composition and heat treatment must be made.

Before a magnetic test can be of service as an indicator of the mechanical characteristics in any particular case, preliminary work must be done to determine the most suitable magnetic data and also the minimum amount which will give the desired information. Among the magnetic characteristics which may be used are permeability, residual induction, coercive force, hysteresis energy, etc., and each of these may be taken in connection with any one of a great number of magnetizing forces.

For a concrete case, suppose that the problem is to devise a magnetic test for a steel spring or a crank axle. The preliminary investigation would take some such course as the following:

1. Determination of magnetic normal induction curves and hysteresis data for test pieces made of the materials to be tested and submitted to the various heat and mechanical treatments that may be expected in practice.

2. Comparison of the above magnetic data with the corresponding mechanical data and the determination of the most suitable magnetic data to use.

3. Working out of the experimental details so that the required magnetic measurements may be made on the full-size commercial specimen.

4. Checking out of magnetic and mechanical data on the full-size specimens to be sure that the same conditions are fulfilled as in the case of the original test pieces.

Operations 1, 2, and 4 are time consuming, but do not offer any great difficulties that cannot be overcome by patient intelligent experimentation. The third operation may offer practical difficulties due to irregularities in the shape of the material to be tested. Relatively long objects uniform in diameter, such as rails, steel rims, band saws, drills, and steel cables, present no difficulty. Relatively long objects whose cross-section changes gradually from section to section, such as spring leaves, straight axles, and files, present comparatively little difficulty. Relatively long objects of irregular section, such as crank axles, present great but not insuperable difficulty. Short, thick castings present difficulties which for the present seem insuperable.—*Scientific Paper, No. 272, of the Bureau of Standards.*

Noise is Wasted Energy

A noisy factory is an inefficient factory. The clatter of worn and poorly adjusted gearings as they engage and disengage is unnecessary, is misdirected and often wasted energy. In a very exact sense, absence of noise in a factory is an index of its efficiency. When you find noisy gearing, bumping, squeaking or grinding contacts their energy is being wasted. Noise annoys and distracts. It breeds mental confusion. Of two factories of the same type, the quieter, busy one is apt to be the more efficient. Noise-prevention, therefore, is generally waste-prevention.

Fighting Noise Consumes Energy

Noise occupies too big a place on your office pay roll. The more noise, outside and inside, the larger the figure it cuts. Psychologists are all agreed that any man or woman working in the midst of distracting sounds or sights, must use up a certain amount of nervous and physical energy to shut these out and keep them from interfering with the task in hand. Fighting noise, in a word, consumes strength and attention which should be saved for the day's work. Fatigue follows sooner than the actual tasks should entail; ability to concentrate goes; inefficiency and high expense are the final results.

The Dandelion

A New Field Product with Various Uses

Of the many exotic plants which have been introduced into this country, the dandelion is more thoroughly naturalized and better known than any other. Of what country it is a native is not easy to say, but it was known to the Romans, who probably introduced it into western Europe from the region of the Himalayas. The dandelion is a plant about which there is a good deal of curious information and it has a great many uses. The celebrated botanist, Linnaeus, selected the dandelion to form his floral flock, for its bright yellow flowers open in the morning between 5 and 6 o'clock and close in the evening between 8 and 9. It takes its common name from *dent de lion*, or lion's tooth, from the leaves being supposed to resemble the teeth of a lion.

One often hears the statement that every production of nature is good in its kind, and the dandelion is not an exception, for every part of the plant is in repute for its particular purposes. In recent years it has acquired a degree of importance which, on that account, entitles it to notice. Its cultivation in the United States does not date back very far, but it is highly probable that it will become a plant of considerable commercial value. It is, perhaps, one of the most cosmopolitan of medical plants, for besides being an actually recognized article in pharmacy, it is also largely collected and used by the country people for liver complaints and in cases of dyspepsia. The roots are used in a variety of ways in Europe and in parts of this country. One useful form is that of a paste, which is made by pounding the fresh roots, placing the mass into tins or jars, and baking it in an oven until it is thoroughly dry. It is used also as a substitute for coffee. For this purpose the roots

Gathering the dandelion crop.

are washed, dried in the sun and cut into small pieces, after which they are roasted in a manner similar to coffee. The material is then ground, and to every nine parts of coffee one part of ground dandelion-root is added. This is said to form an excellent and useful beverage.

The use of dandelion leaves as a pot herb or salad in the early spring is well known in this country. The country people make from them a tonic recommended for purifying the blood. Its use for the table has become so universal that in a number of places large fields are devoted entirely to its culture. The leaves when boiled form a very agreeable substitute for the spinach and other greens at a much earlier period of the season than that in which any other plant is found to ripen in this climate. The flowers are used for making so-called dandelion wine.

Botanists distinguish several species of dandelion, but the one to which the cultivated varieties belong is the *Taraxacum denslionis*. Time and culture have done much for improvement, and to-day it might seem as though the several large-leaved varieties, which are of French origin, and our common dandelion of the lawn and fence rows, had nothing in common except the name. Some of these forms have very large and beautifully-curled leaves resembling the endive plant. The bulk of the dandelion that comes to market during the spring of the year is the wild-grown kind, but the material raised in hotbeds or in well-cared-for fields is more pleasing to the housewife, and is, consequently, more marketable than the natural-grown kind.

Regarding the culture of the dandelion, there are no published accounts on the subject except in a general way, which practically every gardener or farmer knows. It is only requisite to have land of a deep, moderately moist and sandy, friable loam, and to keep it free from weeds. The seeds are sown in rows in the spring where the plants are to stand. Although the small plants may be transplanted, this would be too expensive and without advantage. The plants should stand about one foot apart each way, and a good crop will cover the land completely when the plants are a year old. The ground must be well hoed during the summer, and earthed up in the winter to guard the plants against heaving. The tops may be cut off the following spring when they are ready for the market.

In harvesting the crop, a man with a hoe goes ahead in a row and cuts the tops off at the ground. Others follow, pick them up, pull off the dead leaves, and take them in large baskets to the shed where they are

A dandelion field near New Haven, Conn.

thrown in running water and washed. They are then put up for market. The cutting of the first year's crop stimulates the growth of young plants, which spring up from the tap root in large clusters, producing a much larger crop the second year than the first, but it is claimed by some that the second year's crop is not as good as that of the first. The plants are not allowed to grow more than two years. The dandelion is not affected by any serious disease, making it easier to grow than most crops.

The industry is still localized around New York, New Haven, and Boston; but after the American growers learn to realize something for the dandelion roots, as well as for the tops, it will render it a still more valuable article of growth. At the present time our supply of dandelion roots comes chiefly from Germany, Austria, and France. The United States imports many tons of these roots annually, and there is no reason why the American truck gardeners should not supply this demand. Of the comparative medicinal qualities of the American and foreign-grown roots numerous experiments have been made, and it has been found that the foreign root contains no one essential quality which is not possessed in an equal degree by our own; it is in some cases even more effectual than the foreign roots.

There is no artifice required in preparing the roots for market. They need not be rasped or colored to give them an improved outward appearance, but all that has to be doné is to remove all the earth and dirt by washing them in cold water and drying them thoroughly. The root has been for many years cultivated to a considerable extent in Europe, and that which has come to this country for medicinal use has usually not been very clean of sand and dirt, as the trade should demand. However, the bulk of the material which now comes from Europe is from the natural-grown plants which are dug up in late fall or early spring, because the roots then contain the entire juice and virtue of their medicinal properties; those taken up in summer are of a light and spongy texture and unfit for use.

The roots being cleaned and stripped of all the leaves, are placed on a drying rack or long table in the shade. They are turned frequently, but great care is taken not to break any of the roots while they are still fresh or the whitish, viscid juice would exude under the broken ends and would not incorporate with the tissue of the root. If this juice is allowed to escape or run out, the roots become light, often unserviceable. The roots must be dried immediately after they are taken out of the ground or they will become soft and decay very rapidly. In some instances they are hung up on strings or thin ropes stretched across the drying room, but they will become thoroughly dry in about two or three weeks and arrive at their full perfection.

These directions might be easily and judiciously followed by the gardeners who cultivate dandelions for the tops in this country, except for the fact that our climate may be at times too damp to effect a complete drying during the late fall. It has, however, been recommended to use a room heated artificially, but it is believed that the object would be equally well attained by placing them on a table under the roof of the house or a dry shed. They lose about two thirds of their weight in drying, and when well prepared should be dry, firm and solid, breaking with a short, easy fracture. On a freshly fractured surface is seen a bright-yellow porous inner part, and a white mealy outer portion surrounded by a thin, dark-colored, epidermal layer. They have a bitter, slightly astringent taste and peculiar flavor, with an aromatic quality not manifested to the smell. The root is sold by wholesale druggists at from 22 to 28 cents a pound.

Water Hyacinths in the Panama Canal

One of the minor problems of the Panama Canal is the extermination of the water hyacinth, a plant that threatened to create a serious obstruction in Gatun Lake and the waters in the vicinity, and might possibly extend to the entire waterway. This vigorous plant, technically known as *Eichornia azurea*, is found in nearly all waters of the Atlantic slope from Colombia to Costa Rica, especially in the more sluggish streams, and is closely related to *Eichornia crassipes* of Florida and Louisiana. The plant is propagated principally from seeds, and grows on almost any kind of bottom, in water from one to sixteen feet deep.

Young submerged plants have long, narrow leaves three sixteenths of an inch wide by about three and a half inches long, at intervals of about an eighth of an inch on opposite sides of the stem and very regularly. When the plant reaches the surface these leaves change in form, becoming from three to six inches wide and five to eight inches long, pointed at the outer end, and tapering to the stem. The stem, or root, below water is very tough and ropelike, while above water it is thicker, tough and porous, and follows along the surface of the water, sending out branches every ten inches,

Drying the root for medicinal use.

which in turn also branch, the plant thus eventually forming a thick mass of matted growth bound together by many small matted roots two or three feet long, which appear along the main stem as the plant grows. So solid are these masses that a bed six months old will support a man standing on a six-inch board.

The young plants will grow from one half to three fourths of an inch a day when submerged, and two to three inches after reaching the surface. A healthy plant blooms in about six weeks after it reaches the surface, and two weeks later the flower has died and seed pods formed. Each plant produces two or more stems of 35 to 45 purple flowers a month, or about 25 a year, a seed pod containing on an average of 170 seeds forming at the base of each flower. It will be seen that each healthy plant distributes about 170,000 seeds.

It is thought that the original beds of hyacinths resulted from seed brought down from the upper reaches of the Chagres River by floods, and that while some success has been had in poisoning the plant, the most effective way of eradicating the growth appears to be by pulling up the plants before they reach the seed period. This operation must be repeated a number of times, as the seeds appear to germinate for at least a year after they have been deposited. The work of exterminating the hyacinth has been going on for about two years, and it will take at least another year of constant and vigilant work to complete the task.

A New Thermo-Galvanometer

An interesting type of thermo-galvanometer has been described by F. W. Jordan in the *Proceedings* of the Physical Society. The current to be measured is made or broken through a heater of small thermal capacity located in an air chamber, and the outrush of the suddenly heated air through an orifice deflects a small suspended vane. The disturbing effect of extraneous heat and pulsations of external pressure are compensated; and in one instrument with which experiments were made the sensibility was 4 millimeters per microwatt, and the extremity of throw of the vane was attained in two seconds.

Ancient Mesopotamia

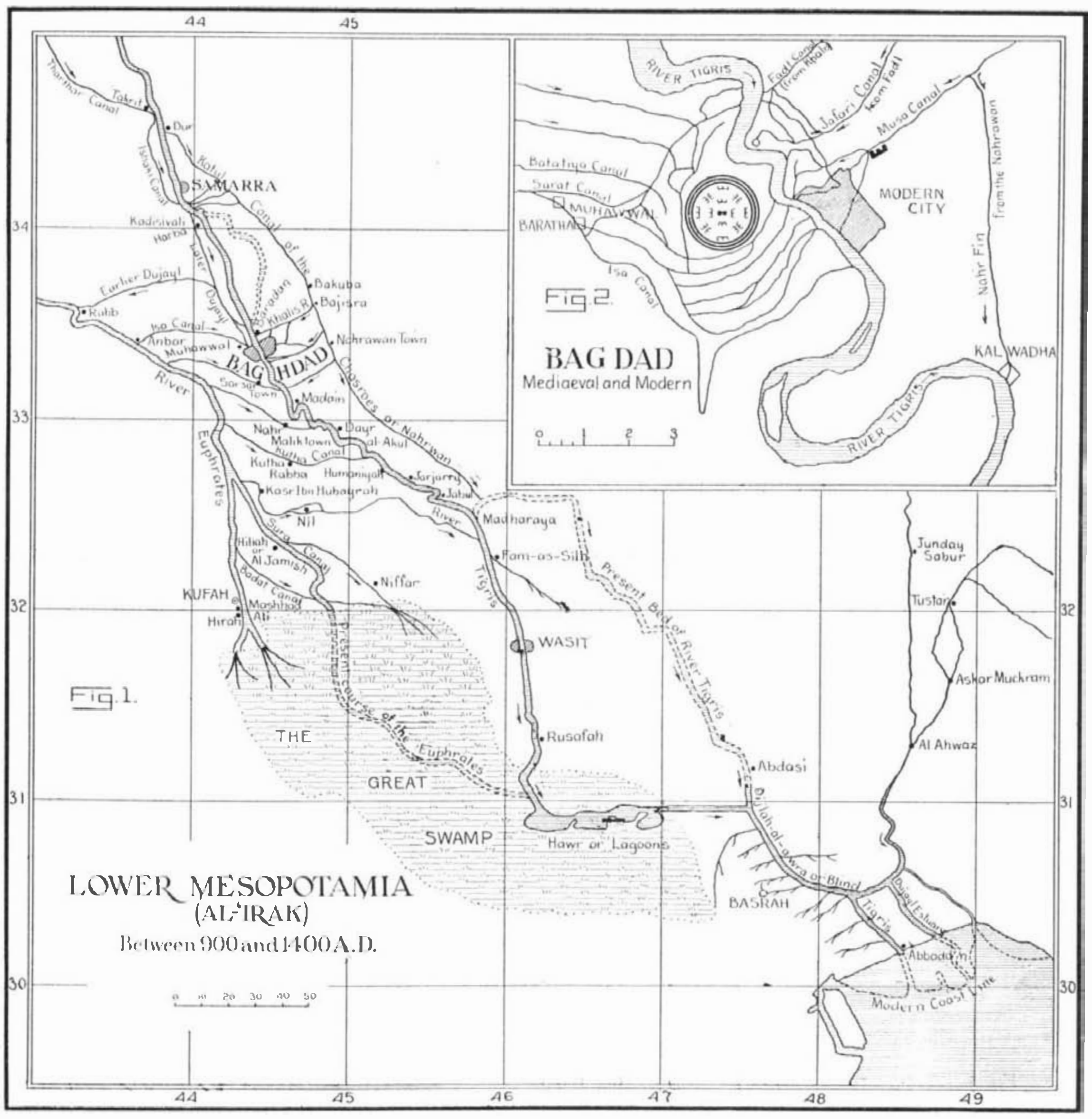
And the Irrigation System That Made It a Fertile Territory

By Dr. Arthur Selwyn-Brown

WELL-DEVELOPED irrigation schemes enabled Mesopotamia, Armenia and other provinces in the near and middle East, formerly to become the seats of mighty empires that possessed great trading centers. To-day, they have comparatively few cities of any importance and their commerce is carried on by caravans. The largest city in Mesopotamia, and the most celebrated, is Bagdad. Its present population is about 150,000, as compared with about 4,000,000 nine centuries ago. The differences between Mesopotamia in the ninth and tenth centuries and to-day were caused by the destruction of the early irrigation works of the Abbasid Caliphs in the fifteenth century.

Bagdad has been the site of important cities from the remotest historical times. But the present city was founded by the Caliph Mansur in A. D. 762. The site was chosen on account of the rich alluvial plains in the vicinity, and the ample water resources of the Tigris and Euphrates rivers. The previous cities of Bagdad were settled by Persians, who carried out irrigation works on a small scale in the plains a little to the south. These works showed that great wealth could be won from the land by means of irrigation, and the Caliphs, who in their travels with their armies in Persia and Arabia learned the value of the accumulation of wealth in times of peace, gave as much attention to the development of irrigation works around Bagdad as they did to the city itself. The result was that about the year A. D. 1000 Bagdad was as celebrated for its canals, gardens and irrigated farms as for its wealth, trade, palaces and mosques.

In the height of prosperity Bagdad possessed the greatest system of irrigation canals that has ever been constructed. In A. D. 1000 the canals in the vicinity of the city measured over 3,000 miles in length. These canals were well built, supplied with storage basins, locks and weirs, bridges and loading docks for barges, and were kept in good order. They fed thousands of miles of ditches carrying the precious water to innumerable small farms. These farms were situated all around Bagdad on both sides of the city. They grew splendid crops of grain, hay, fruit, vegetables, nuts, and flowers from which essential oils and Oriental perfumes were made. And the produce of these rich farms supported a great trade between Bagdad and the whole of Asia.



In addition to the canals around Bagdad there were a large number, both north and south of the city, which joined the Euphrates with the Tigris, and there were several running parallel with the rivers.

The largest of the outside canals was known as the Chosroes Canal. It was built in early historical times to connect Bagdad with the city of Dur, about 100 miles to the north. This great canal was extended by the Caliph Mansur to the city of Madharaya, the modern Kut-el Amara. This gave the canal a length of 290 miles. Later Caliphs carried it 150 miles beyond Dur. Whenever this canal passed through loose soil it was over 200 feet in width and 6 feet deep. Where the ground became rocky it was reduced to width of 40 or 50 feet. This trunk canal carried a large boat traffic and supplied water to hundreds of miles of lateral canals and irrigation ditches. It enabled close settlement to be made over many thousands of miles of splendid farming country.

South of the ancient city of Kufah, on the Euphrates, now called Kerbela, there were great irrigation developments on what was proved to be the richest agricultural land in Asia. The Euphrates has since shifted its bed about 30 miles eastward of its old course and the rich canal lands are now nothing but unhealthy reedy swamps, the haunts of large herds of water buffaloes, cranes and other animals and birds. Between Dur and Basorah there were over fifty trunk canals joining the Tigris and Euphrates. These canals irrigated an area of about 37,000 square miles of rich farming lands. These lands, called the "Meadows of Gold," were worked to the fullest extent under all the Abbasid Caliphs between the years A. D. 750 and 1258, when Bagdad was sacked by the Mongols, and the rule of the Caliphs ended. After the Mongolian invasion Bagdad was no longer the capital of the Mohammedans, and the Holy City of Islam. It reverted to Persia, and became the capital of the Province of Irak. It was occupied by the Mongols until A. D. 1411 when it fell into the possession of the Black Turkomans, who in turn, in 1469, were dispossessed by the white Turkomans.

The Persians retook Mesopotamia from the White Turkomans in 1508, and, in 1534, they gave way to the Ottoman Turks, who have since retained possession.

A plan of Bagdad, as it was in A. D. 1000 and as it is to-day, is shown in the insert in the map. The shaded portion is the modern city. The principal part of Bagdad is now on the eastern, or left, bank of the Tigris. In the time of the Caliphs, the city chiefly occupied the opposite side of the river. The circles in this chart represent the Round City, which was founded by the Caliph Mansur in A. D. 762. It was surrounded by three thick brick walls, perfectly circular, with a moat inside. There were four gates leading out of the city connecting with two main thoroughfares crossing through the city at right angles to each other. These four equidistant gates were a little more than a mile and a half apart—the same distance as the diameter of the inner city wall. There was a splendid circular park in the center of the walled city in which was situated the palace of the Caliph, known as the Golden Gate Palace. A lovely mosque also occupied this park. Around these buildings there were other important edifices grouped in circular form, as is shown in the illustration. Chief among these were the mosques of Waddah and Sharkeyah, the royal palaces and the government buildings.

The walls of this city were built of large sun-dried bricks 18 inches square. The inner wall was 90 feet high and 105 feet thick at the base. It tapered to 38 feet at the top. The outer wall was about 70 feet high, 75 feet thick at the base and tapered to 32 feet at the top. Twenty-eight forts were placed on the top of the intermediate wall. These were spaced equidistant around the city. Each gateway, known as the Basorah, Kufah, Khorasan, and Syrian gates, was closed by iron doors, which were so large and heavy that it took a full company of the military guards to open and close them. These doors were built up from sheet metal on strong iron frames. The city was well laid out by architects, and furnished with numerous parks and public squares. Beautiful flower beds were kept in the parks and made Bagdad celebrated for its flowers. The circular city was kept for residential purposes only, and for the numerous governmental and military offices. This is the first recorded instance of an Oriental city being laid out in this artistic manner. It was so well done, however, as to indicate that town planning was a well-developed art in Asia in the eighth century.

No traders were allowed to settle within the walled city. Consequently commercial people settled outside near the various gates. This resulted in the wide development of Bagdad beyond the walls of the circular town.

The lines in Fig. 1, encircling the walled city, represent the principal irrigation canals. The whole area covered by the canals was thickly settled. There were numerous public gardens, mosques and royal palaces throughout the area covered by the canals.

The principal canals joining the Euphrates with the Tigris are shown in Fig. 2. This map is copied from the reconstructed plans of G. Le Strange, who followed the works of the Arab historians Tabari, Ya'kubi, Khatib, Serapion and others.[1]

To the east of the Tigris the great trunk canal of the Chosroes is prominent. This great canal skirted the alluvial plains of the Tigris valley from the old city of Hit, of the Hittites.

The destruction caused by the Mongols has never been made good. The wrecked canals were never repaired, and as a result the whole country again became a desert.

The whole of the valleys adjacent to the courses of the Tigris and Euphrates are irrigible. Both the land and climate are suited to a great variety of tropical and sub-tropical crops. And the natives are good and painstaking agriculturists. With sound government, security of tenure, cheap transportation facilities and modern irrigation systems, the plains of Armenia, Babylon and Mesopotamia can be quickly made to bloom again.

There can be no doubt that the Bagdad railroad will be constructed immediately after the war is over. There are definite commercial factors, quite aside from the well-established political reasons that will make the construction of this railroad imperative. Then a new system will be run from the Black Sea port of Trebizond, southward to Bagdad, along the course of the Euphrates. The road will traverse the sites of numerous old irrigation centers. It will, for instance, pass through the old irrigation fields of Babylon and Nineveh. And much farther north, innumerable ruins of ancient cities will be met where large settlements existed which entirely depended on irrigation.

[1] See *Journal* of the Royal Asiatic Society, 1895.

Food Economics*

The Limitation of the Quantity of Food to a Sufficiency

By Harry Campbell, M.D., Lond., F.R.C.P. Lond.

Food not only occupies the unique position among the different forms of wealth of being the only one which is essential to life: it has the further characteristic (in common with a few other commodities, such as alcohol, tobacco, coal, and gasoline) that its use involves its immediate destruction. The clothes we wear may last us months, even years, our dwellings may outlast centuries, but the food we eat is rapidly consumed within the body. It will thus be seen that any consumption of food beyond what is actually needful constitutes a net waste of the most important form of wealth, and this at the time when the strictest economy is called for. Those who delight in ethical subtleties might take as an interesting subject for discussion the question whether the thief or the glutton is the greater sinner. It would be open to anyone to argue that robbery is a less deadly sin than gluttony, seeing that the one consists in a mere transference of weath, while the other involves a useless and even harmful destruction of it. Many people eat more than they require; not a few as much as would suffice for two, nay, even three persons. A saving of wealth running into millions could be effected if only those who exceed were to reduce their rations to the actual needs of the body. Excessive eating not only constitutes a waste of national wealth, it also injures the health. It is a trite but true saying that more people die from over-eating than from over-drinking. The transgressor in diet, moreover, is less efficient as a citizen, and at the present time we all need to be at our very best, mentally and physically. Yet I see little attempt in clubs and restaurants to economize in food. I recently estimated that the regulation supply of food at a prominent London club was about twice the quantity actually necessary, and a large proportion of the habitués gave evidence of the havoc which prolonged over-eating had wrought in their tissues. I lately heard a visitor to a country hotel remark to the landlord upon the abundance of the fare he provided. "Yes," was the proud rejoinder, "this is a house of plenty." At the fashionable West End restaurants food and drink are as lavishly consumed at the present time of crisis as in the piping times of peace. I think it possible that food is supplied too generously in some of our public institutions. At a large London workhouse which I visited some years ago it seemed to me that the supply of bread was more than necessary, certainly in the case of some of the inmates.

I am convinced that the quantity of food required to maintain in health a person not engaged in strenuous muscular exercise is much less than is generally supposed. Young adults need more food than other people —our food requirements diminish with advancing years —yet it is surprising how small an amount of food even young people leading active lives can thrive on. Thus the diet of a young woman, weight 140 lbs., the embodiment of healthy womanhood, whose daily routine is one long round of activity—bustling about the house, riding, driving, walking, etc., is somewhat as follows: Breakfast: A little bacon or fish, or an egg, with a couple of slices of bread-and-butter. Midday dinner: Equivalent to what a town-dweller would regard as a moderate lunch. Tea: A little bread-and-butter. Before going to bed: An apple or some other fruit. On this diet she keeps her weight, looks a picture of radiant health, never feels tired or unpleasantly hungry, and can always forego a meal without discomfort. The following is the diet of a London postman, aged 26, who walks about 15 miles in the day, and on some beats has to mount some 5,000 steps daily (he carries a weight not exceeding 30 pounds): 5 A. M., a piece of toast and a cup of tea; 9 A. M., one rasher of bacon, four moderate slices of bread-and-butter, two cups of tea; 2 P. M., chop or cut off the joint, four potatoes and green vegetables; 6 P. M., a bloater (or some other fish), four slices of bread-and-butter, one cup of tea. I could furnish many similar instances. Cases of this kind—and they are quite common—show how little food is needed in perfect health, even in the heyday of youth, and when a considerable amount of muscular work is being performed. They probably indicate the possession of a well-nigh ideal digestion. Others apparently healthy no doubt require a somewhat more generous diet.

The two chief factors which make for excessive eating are the appetizing nature of the food and the softness of the vegetable (especially the farinaceous) portion of it. The object of the cook is to make her dishes as tasty as possible, and so to arrange their order that the appetite shall not flag throughout the meal. As to the second factor, it is obvious that soft farinaceous foods, such as porridge and milk puddings, which rapidly find their way into the stomach, are more likely to be taken in excess than firmer food, such as crusty bread, which calls for thorough mastication. The more completely farinaceous food is masticated the smaller is the quantity that will be needed to satisfy the appetite.

Another cause of excessive eating depends upon the principle that "appetite increases by what it feeds on." The more one accustomes oneself to eat largely the more clamant does the appetite become. Excessive eating, indeed, tends to beget an actual craving for food not unlike the morbid craving for stimulants. When the meal time comes round, or even before, there is felt a sinking or other uncomfortable sensation at the pit of the stomach, or perhaps a feeling of lassitude. These feelings being relieved by food, it is erroneously concluded that they indicate the need for a restoking of the vital engine. That this view is entirely wrong is shown by the fact that many a healthy person, expending a good deal of muscular energy and consuming but a moderate quantity of food, can forego a meal without inconvenience. Even more significant is the fact that the habitual over-eater generally feels brighter and more vigorous after enforced abstinence, such as may be necessitated, e. g., by a bilious headache or an attack of gout. The machine is found to work better when the stoking ceases. The fact is, the unpleasant feelings referred to are not due to the lack of nutriment and do not indicate the need for more. The "sinking" results from the absence of the wanted mechanical stimulus afforded by a bulky meal; the lassitude is due to a poisoned state of the blood brought about by chronic over-eating, and is removed temporarily by the absorption of the more diffusible, stimulating elements of the food. In this way the effects of the blood poisoning are for the time masked.

The over-eater, like the alcoholic inebriate, rarely realizes that he is indulging in an injurious excess. In deciding whether too much food is being taken or not, the body weight affords useful help. If a person's weight is not above the normal the probability is that he is not eating too much, but if he is decidedly stout he very probably is over-eating. This test is not, indeed, infallible; we occasionally meet with thin people who eat abundantly and stout people who are moderate eaters. What is so frequently forgotten is the fact that the amount of food taken should be proportioned to the amount of muscular energy expended. If a person takes little exercise he requires proportionately less food, just as it requires less gasoline to drive a car 5 miles than 50. When a person who takes little exercise gets fat his fatness should not be put down to the lack of exercise, but rather to the fact that his supply of food is in excess of the amount of muscular energy expended. The London policeman probably consumes as much as the London postman, although he does not expend more than a quarter of the muscular energy expended by the latter. It is clear, therefore, that he eats more than is necessary—a conclusion which is not infrequently borne out by the amplitude of his proportions. It is as rare to meet a thin policeman past 30 in our towns as it is to see a stout postman anywhere. Stout people often resent the charge that they eat too much, and insist that they are very moderate eaters. Investigation generally shows otherwise, but whether they eat much or little the fact remains that in the vast majority of cases they eat more than they require.

All those who on reflection have reason to suspect that they may be eating superabundantly should, alike in their own and nation's interest, cautiously begin at once to cut down their rations. In this way they can improve their health, render themselves more efficient citizens, and save the wealth of their country. It is not suggested that a large reduction should be made suddenly. Rather should an attempt be made to accustom the body gradually to do with less and less food. To this end the food should be plain, not too appetizing, and well masticated. Unfortunately, the British people are the most inefficient masticators in the world. I will now endeavor to explain how this bad habit has arisen, and to indicate some of the evils which result from it.

Mastication.—Efficient mastication, among other advantages, makes for economy in food, inasmuch as it promotes normal digestion and in this way reduces the amount of food needful to sustain the body. It is not generally known that it is essentially the vegetable portion of our food which demands mastication. The carnivora do not masticate their food, as anyone who has observed a dog bolt a piece of meat can testify; their teeth interlock and do not admit of any lateral grinding action. On the other hand, all the vegetable-feeding mammals are laborious masticators. This is because vegetable food consists of a cellulose framework more or less dense, which it is necessary to break up, so as to liberate the contained nutrient particles and allow them to come under the action of the digestive juices. That our ape ancestors subjected their food to prolonged mastication is evident from a study of the teeth of their near relatives, the larger manlike apes (gorilla, champanzee, and ourang). I find that even the milk teeth of these animals are greatly worn down. Before man learned to prepare his vegetable food artificially by maceration, grinding and cooking, he had to subject most of it to a prolonged natural milling with his teeth. Our teeth have been to a great extent relieved of this laborious work by the miller and the cook. The saving of the work of mastication thus effected has certain manifest advantages, but these are largely discounted if the farinaceous food is rendered so soft that it is swallowed without being subjected to any but the merest pretence at mastication, for then not only is it not properly mixed with the saliva, but the teeth and the salivary glands are cheated of their normal work. Now, unfortunately, in this country we consume all, or nearly all, our vegetable food in soft, pappy, pultaceous and spongy forms, with the result that we have come to be a nation of veritable food-suckers, with atrocious teeth, misshapen jaws, and none too good digestions. Our sole vegetable foods which invite mastication are crusty bread, dry toast, hard biscuits, salads, nuts, and apples. Our staple vegetable food, bread, is eaten in a spongy form. The loaves are shaped so as to give a minimum of surface for crust, and are lightly baked so that the crust shall be as thin as possible. In the "A. B. C." shops it is the custom when cutting the rectangular loaves into slices to put aside the end pieces, as the customers refuse to eat them. I am told by a Scotch baker that the most crusty loaves—those which rest on the floor and against the sides of the oven—fetch a lower price than the others, so rooted is the objection of the Scotch people to crusty bread.

Let us now consider the foods which form the bulk of our national vegetable diet. They are: soft, spongy bread, bread-and-milk, cooked vegetables, puddings (suet, batter, "Yorkshire," plum, cabinet, milk, etc.), porridge, cakes (multitudinous), buns, scones, muffins, crumpets, tea-cakes, and fancy cakes galore. To set forth in detail the many evils which result from this pernicious system of diet would require several articles. The one I desire to emphasize just now is that it causes an excess of farinaceous food to be consumed. The more thoroughly a farinaceous food, such as bread, is chewed, the more intimately will it be mixed with the saliva, and the more efficiently is it likely to be digested; and it goes without saying that when food is well digested less of it will be required than when it is not. A piece of crusty bread, thoroughly masticated, will go a longer way to satisfy the appetite and the nutritive requirements of the system than an equivalent of pudding hastily swallowed.

The best way to secure adequate mastication is to choose foods which invite, or even compel, mastication. It is chiefly in regard to the cereal foods—wheaten flour, oatmeal and rice—that reform is most needed. From the point of view of mastication oatmeal biscuits are preferable to oatmeal porridge, but the latter is so popular and valuable a food that it may be permitted with the proviso that it be subjected to some sort of chewing, and not allowed to flop like some huge poultice into the stomach. Wheaten flour—our staple vegetable food—should be employed for little else than bread, suet pudding (plain suet pudding, fruit pudding, meat pudding), plain biscuits, and home-made cake. Other puddings and the multitudinous varieties of cakes known to the pastry cooks should be banned; they have no special virtue and they can well be dispensed with. When a patient is knocked off his puddings or "sweets" by his doctor he often asks in a concerned or even injured tone what he can eat instead? The answer is that bread-and-butter (i. e., flour and fat) is as nutritious as any ordinary pudding and more wholesome than most. It is a good food because it is nutritive, simple, and (if the bread is crusty) compels mastication. It is, of course, chiefly in the form of bread that wheaten

*The Lancet.

flour should be consumed. The loaves should be shaped so as to give a maximum surface for crust (spindle-shaped, or cylindrical-shaped) and well baked, so as to give a thick but not too hard or brittle crust. Unfortunately, many people are prveented by bad teeth from eating crusts.

Defective teeth.—Here I am led to say a few words about the deplorable condition of the teeth of our countrymen, the more so as the fact has recently been brought into prominent notice in connection with our recruits. This state of things is a national disgrace. It is solely due to our faulty dietetic customs—above all to the practice of eating sweets and soft farinaceous food, which leaves the mouth in a chronic unhygenic condition. I estimate that there are among the inhabitants of these islands upwards of 200,000,000 of carious teeth, and probably an even greater number of socket abscesses (pyorrhœa alveolaris), while as to the jaws, it is rare to meet a normal one. One of the first things which strike the observant foreigner when he lands upon our shores is the large number of people with false teeth, and the great length and prominence of the natural teeth—a feature which the continental cartoonist has not been slow to accentuate. These obtrusively large teeth constitute a damning indictment against our habit of consuming nearly all our vegetable food in a form which does not put the teeth to adequate use. Teeth which are not put to vigorous use are not ground down as they should be, and they tend also to "grow out of their sockets," so that they, or rather the visible parts of them, become longer. This lengthening of the teeth is due in an even greater degree to pyorrhœa. Hence pap-fed people tend to be "long in the tooth."

We are happily beginning to awake to the necessity of looking after our children's teeth, and dental surgeons have been appointed to tend the teeth of the elementary-school children. This is a move in the right direction, but it is little more than shutting the stable door after the horse has bolted. Dentists are mainly engaged in an endeavor to repair damaged teeth. Obviously our aim should be to prevent the damage, and this, as Dr. Sim Wallace has shown, can be done by choosing foods which exercise the teeth and salivary glands adequately, and by so arranging the order of them in a meal that the mouth shall be left in a sanitary condition.

So accustomed are we to the prevalence of dental disease in this country that we accept it as a matter of course. It is, however, a serious national evil, but happily one which can be remedied. The present time, when for reason of economy we are called upon to examine into and revise our dietetic habits, is a good one to put up a bold fight against it.

Portland Cement

In connection with its educational exhibition work the Division of Mineral Technology of the National Museum has just completed a model of a Portland cement plant and placed it on exhibition in the southwest corner of the older building.

This model is a miniature of a real cement plant and covers eighty square feet, its design and layout being such as to enable the visitor to follow successively the various steps of the process.

This exhibit is the most recent achievement of one of the museum's newest divisions, mineral technology, which was organized about three years ago to increase the popular knowledge of the mineral industries of this country and to further the understanding of the adaptability of the derived products.

Portland cement may be defined as a product made by burning limestone and clay, which have been mixed so as to form a certain composition, and grinding the resulting "clinker" to powder.

In the early days much mystery surrounded the manufacture of Portland cement when it was first discovered by a bricklayer of Leeds, England. He found that by mixing water with a compound of Thames chalk and Medway mud he could compound an artificial water cement, and determined that no one should discover his secret. When employed in manufacturing his raw mixture, he is said to have attired himself in a long black gown and the pointed hat of the mystic, and to have recited mysterious incantations during his operations.

But a curious onlooker, who determined to ascertain his ingredients and methods, had a sample analyzed by a chemist, whose result showed 90 per cent phosphate of lime. Thinking that he had solved the secret, he began to calcine all the bones he could gather up in the village, much to the discomfort and objections of his neighbors, who finally induced him to desist. Following, however, the old system of cut-and-try, he finally solved the problem and eventually produced a cement equal to that of the original compounder, and the great industry began at once to thrive.

In this country the Portland cement industry had its beginnings in the Lehigh Valley in Pennsylvania, chiefly in Lehigh and Northampton counties, where John W. Eckert, a chemist, discovered that there occurred a limestone composed of approximately the correct ingredients necessary for the manufacture of Portland cement. The model represents the process of manufacture used in this section of Pennsylvania, where the limestone that is used is termed cement rock.

Note on the Transparency of the Atmosphere in Central Australia

Many observers have borne witness to the remarkable clearness of the atmosphere in the center of the Australian continent. Thus the Carnegie Magnetic Survey party, in 1912, were much impressed by this feature and by its bearing on astronomical observation. It was stated that from one point on the Great Northern Railway they could see the smoke of a train at William Creek, forty-five miles distant, and by the movements of the smoke column could follow the operation of truck-shunting then in progress. The best definition noted by them, however, judging by the sharpness and steadiness of the images of the sun and stars in the theodolite, was obtained in the region near Blood's Creek, between Oodnadatta and Charlotte Waters. It may be remarked that these observations were made in May and June, and that the atmosphere in Central Australia is undoubtedly at its best, especially in the day time, during the cold months. As the summer comes on the great heat causes pronounced mirage effects, which begin to disturb the definition soon after sunrise. An instance of this in the month of October was noted by the writer while taking theodolite bearings of a survey mark known as Table Pile, situated on an extensive table-topped formation near the Upper Arckaringa Creek. This object was quite distinct in the theodolite at sunrise, but the sun's rays soon began to take effect, and within less than one hour after sunrise it was entirely lost from view, together with other details of the hori zon, in a continuous mirage movement rippling across the field of view of the theodolite. A month earlier, however, the remarkable visibility of objects at a great distance was noted in an observation made at the top of the Moorilyanna Hills. The highest peak rises to some 400 feet above the level of the neighboring plateau, which is approximately 1,700 feet above sea level. From the hilltop, Mount Illbillee, 35 miles distant, and other features of the Everard Ranges, were very distinct, and through binoculars, the dark, peculiarly shaped outline of Mount Ferdinand, the nearest peak of the Musgrave Ranges, rising to a height of 4,000 feet above sea level, and 64 miles distant from Moorilyanna, was plainly visible, just projecting above the horizon. The part played by refraction in cold weather was here seen in an interesting manner. From the magnetic station at the foot of the Moorilyanna Hills a gap was noticeable in some rising ground to the west-southwest. Mount Illbillee lay just behind this gap. As a rule, during the warmer part of the day, when also, owing to the large diurnal variation in high level country, the atmospheric pressure was reduced, the peak of Mount Illbillee remained just below the level of the gap, but in the colder hours of the morning or evening, the increased refraction caused it apparently to be lifted up above the level of the nearer object and to become visible in the theodolite through the gap. A similar effect of refraction has been noted at some of the stations in Central Australia, and local weather prophets have been known to make use of it in foretelling the weather in those parts.

An additional suggestion of the transparency of the atmosphere in these regions is afforded in the stereoscopic appearance of many of the hills, which, at five or ten miles distance, stand out boldly as if in relief, the background of the sky not blending with their outline, as is the case in a more hazy atmosphere, but appearing much farther behind. Connected with this phenomenon is the impression of a larger and deeper sky dome characteristic of Central Australia. This effect is also more pronounced in the cold months, and has been noted in the upper parts of the Flinders Ranges as well as in the interior. There is also to be perceived a remarkable blueness in the shadow tones toward sunset, and, after the sun has gone down, the space of sky illuminated by the last rays is much smaller than is customary with us in the south. In a typical case, the area of clear sky tinged with red just after the rim of the sun had disappeared was only 7 degrees in diameter. On the whole it would appear that on the elevated table lands of Central Australia, there are places, which could be chosen for occasional special astronomical investigations, demanding clearness of atmosphere and steadiness of definition, probably unsurpassed in any other country. The very low percentage of cloud is also a favorable condition for such work, there being frequently long unbroken periods when the sky is not dimmed by a vestige of cloud by day or night.—G. F. Dodwell, Government Astronomer, in *Bulletin No. 6 of the Geological Survey of Southern Australia.*

Utilizing Western Lignites

To one thoroughly familiar with the great extent of the Western lignite deposits, their limited development, and the comparatively simple methods that have thus far been adopted in their utilization as fuel, any investigations looking to a possible and increased utilization of these vast deposits must at once be considered of great economic importance. There is no doubt but that much can be done toward improving the methods of burning now in use, and in providing means for using the coal in other forms, such as in a pulverized state, or in the manufacture of producer gas, or of by-product gas, or as residue briquets. Especial attention has been given by the writer to the study of utilizing the lignite in the form of residue briquets and in the manufacture of by-product gas, because in this method there appear excellent possibilities of providing a satisfactory and efficient fuel and of recovering numerous by products.

From the results obtained by the methods being developed at the School of Mines and the substation of the University of North Dakota there seems little doubt but that the briquetting and the production of gas from lignite can in the near future be put on a commercially satisfactory basis.

Because of the ease with which the gas is produced, the low price of the original lignite, the value of the residue, and the low price for which it could be sold if manufactured in a plant used to produce briquets from the residue, the lignite gas should have a large commercial utilization for heating, lighting, and power purposes. It has been found that briquets made from this concentrated residue produce a most excellent fuel, for all practical purposes approaching the efficiency of anthracite. One ton of the air-dried lignite will produce from a half to two-thirds of a ton of briquets in addition to 8,000 or 10,000 cubic feet of gas. The briquets have about twelve-thirteenths the actual heating value of hard coal, and they can be shipped for considerable distances and still prove profitable. The briquets present many advantages, especially over the original lignite as usually placed on the market. The heating value is nearly doubled, the briqúets do not disintegrate on standing or burning, they can be stored without being affected by atmospheric conditions, they are uniform in size and are convenient to handle.

No detail statements of the cost of operating a large commercial plant are given for the reason that the cost per ton of briquets and per 1,000 feet of gas and other by-products will depend upon a large number of factors, any one of which may materially affect the cost. For example, the cost of production is much less in a large plant than in a small one, and also less in a plant favorably situated—that is, near a mine, a city, and railway facilities. The use of mine slack, the percentage of moisture in a given lignite deposit, and the relative cheapness of mining and ease of delivery to the plant are all variable conditions and would have to be determined for each individual plant.

The development of methods for the utilization of low-grade coal will prove of much value to those communities nearest the great lignite deposits in the West. In some of these the lignite could be converted into electricity, which in turn could be sent to surrounding towns and villages, thus distributing power and light from numerous central power plants. Such an arrangement would not only be a great saving of our fuel resources, but would also result in the establishment of many industries that can be developed by abundant and cheap electric power.—*From a Report on Economic Methods of Utilizing Western Lignites by E. J. Babcock, Department of the Interior.*

An Old World Chisel

Speaking before a meeting of the Institution of Mechanical Engineers at London, Sir Robert Hadfield said that when in Ceylon he paid a visit to the Colombo Museum, and there found some very extraordinary chisels. He had been somewhat puzzled to understand how, in those days, they got the necessary hardness for cutting purposes. On analyzing the chisel in question it was found to be practically pure iron, so far as the shaft portion was concerned, and as the chisel dated back to the early period of the Christian era it was evident that a knowledge of some method of producing a hardened point to the chisel must have existed at that time, since it was impossible to think of wrought iron being made to accomplish the desired work. It was a curious thing to bear in mind that, in those days, they must have known the art of cementation; if they took wrought iron and embedded it in a charcoal fire, they might get a certain amount of carbon absorbed by the point, which, after quenching, would give a cutting edge.

A corner of the ruin, showing thickness of the walls, and inwall of a kiva.

Collection of carved stones, cemented together for protection.

The Sun Temple in Mesa Verde Park

A Lesson in Ancient American History

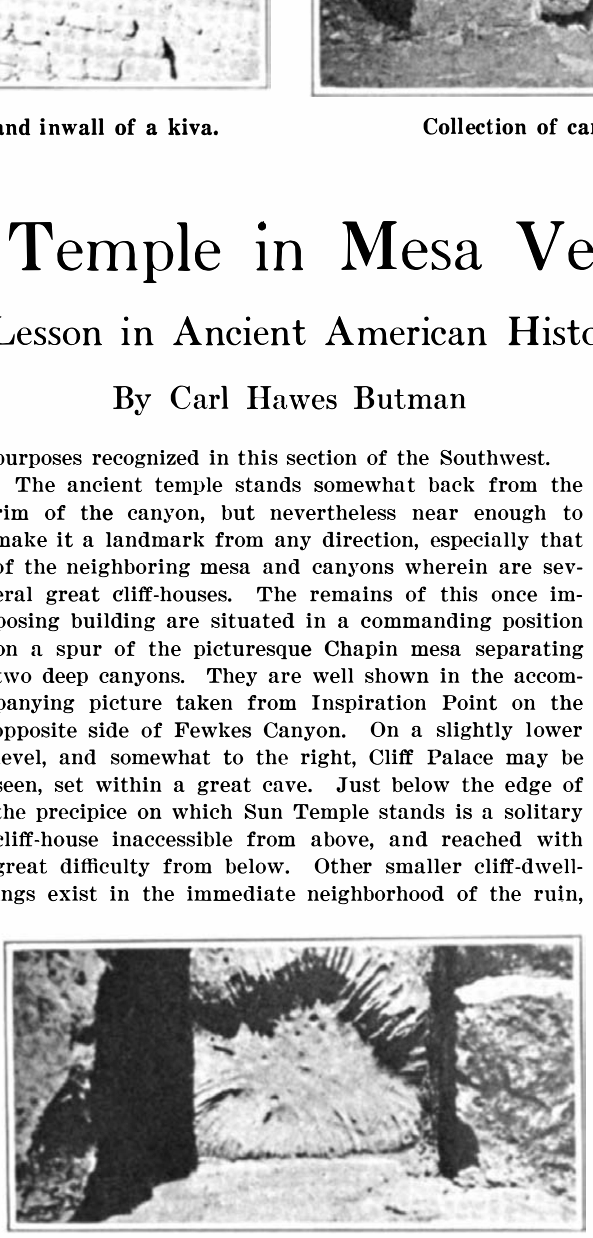
By Carl Hawes Butman

In Uncle Sam's most unique national park, known as the Mesa Verde, and situated in the southwestern corner of Colorado, a remarkable building of great age (possibly dating back to 1300 A.D.) has just been excavated and opened for the inspection of the tourist—and his ultimate approval. It is a ruin of exceptional type, but its purpose is uncertain, although it is believed to have been a religious structure. Its neighboring antiquities number no fewer attractions than the ruin known as Cliff Palace, an ancient domicile where once lived more than one hundred cliff-dwelling Indians; Spruce Tree House, another ancient building in the cliffs whose former inhabitants belonged to the same stock of American aborigines; the dance plaza called Painted House, and several other cliff-dwellings, none of which has a fellow in any other part of the world. These ancient houses of a long since departed branch of the American Indians have been excavated and repaired, and are now protected by representatives of the Interior Department, that future generations may look upon these ancient object lessons in architecture and culture, and learn thereby. Not only is this particular park a veritable free class-room for the student of history, anthropology, architecture, and other special subjects, but it is proving to be of great interest to the casual tourist who journeys in this part of the country, as well as to him who makes it a point to travel through his native land.

Since the park was set aside by Congress from the Ute Reservation in 1906, steady progress has been made in the development of its educational and picturesque features, and, to facilitate access, trails and wagon and automobile roads have been constructed. As rapidly as means afford, the ruined buildings themselves are being excavated and repaired. In this latter work science has had a hand through the co-operation of the Smithsonian Institution and the Interior Department. Dr. J. Walter Fewkes, an ethnologist on the staff of the Smithsonian Bureau of American Ethnology, has been in charge of all the excavation and repair work.

Last summer Dr. Fewkes's work brought to light a mysterious D-shaped building which has excited much interest among students of American anthropology and tourists who were so fortunate as to visit his camp while the work was in progress. Some years ago a large mound composed of rocks and earth covered with trees, among them two giant cedars, had been noticed on the rim of a high promontory overlooking what is known as Fewkes Canyon, a branch of Cliff Canyon, and designated for future excavation, but it was not until August, 1915, that the actual work on it was begun. This mound, which was originally called Community House, has recently been named the Sun Temple. As the excavation of this pile of debris progressed, the walls of a ruin of a type hitherto unknown were uncovered. The building thus brought to light was constructed of the highest class of masonry known to the ancient Indians of the United States, and proved to be the most mysterious ruin in this region. At first there was some doubt as to the use made of this structure by its early builders, although it was soon recognized that it was not constructed for habitation. The present belief is that it was intended for the performance of rites and ceremonies, being the first of its type devoted to religious purposes recognized in this section of the Southwest.

The ancient temple stands somewhat back from the rim of the canyon, but nevertheless near enough to make it a landmark from any direction, especially that of the neighboring mesa and canyons wherein are several great cliff-houses. The remains of this once imposing building are situated in a commanding position on a spur of the picturesque Chapin mesa separating two deep canyons. They are well shown in the accompanying picture taken from Inspiration Point on the opposite side of Fewkes Canyon. On a slightly lower level, and somewhat to the right, Cliff Palace may be seen, set within a great cave. Just below the edge of the precipice on which Sun Temple stands is a solitary cliff-house inaccessible from above, and reached with great difficulty from below. Other smaller cliff-dwellings exist in the immediate neighborhood of the ruin, which seems to have been well situated near the central point of a good-sized prehistoric population, being ideally placed for a religious building in which the cliff-dwellers could gather to perform their ceremonial dramas.



The Sun Shrine, a fossil imprint of the leaf of a palm

The unusual ground-plan has been well compared to the letter D, the straight line of which runs east and west, almost parallel to the rim of the canyon. The structure is divided into two sections, the larger of which is itself D shaped, and may be called the original building, while the smaller, which forms the west end, possibly of later construction, may be known as the annex. The south wall, the back of the D, is common to both sections of the building and extends 121.7 feet in length. The maximum width of the ruin is 64 feet. Its walls average 4 feet in thickness, and are composed of a central core of rubble and adobe with two facings constructed of well-dressed stones. These were not bonded to the core, thus presenting a serious architectural defect. The foundations throughout most of their length rest on the solid rock of the cliff. There are about 28,000 cubic feet of stone masonry still standing.

The rooms include circular and rectangular types, the former being identified as kivas, or sacred rooms, wherein were enacted religious performances; but the purposes of the rectangular rooms are unknown. In the court of the original building there are two large circular kivas of about equal size, while a third of the same type was found near the center of the annex. A little northeast of the last mentioned kiva in the annex there is a circular pit just between the junction of the original wall and the outside wall of the annex; its function, however, is unknown. There are twenty-three other rooms, fourteen of which are in the original building, arranged around the outside wall and separated from the court by a second wall. Several of the rooms in the main building and all of those of the annex were entered from above; there are four rooms opening on the inner court or plaza.

It is supposed that the passageways from one of the encircling rooms to another were topped by wooden beams placed to support the masonry above, but none of these beams was found. The highest of the remaining walls measures 11 feet 7 inches. There are no rows of holes to be seen in the walls to indicate the insertion of floor or roof joists, which shows that the rooms had either very high ceilings or none at all. No sign of plastering on the inside walls is to be seen, but the joints between the stones were carefully pointed with mud and generally chinked with stones. The prints of the fingers and hands of the early workers which remain in the clay-mortar are very small and appear to be the impressions of women's hands. Probably the builders never intended to plaster the inner walls, for then the engraved stones set therein would not have been visible. The inner surface of all these stones was shaped by pecking and sometimes smoothed by rubbing with stone implements. The stones in the different tiers rarely ever overlapped, neither were the side walls bonded, but nevertheless these walls held together well, owing to the careful workmanship and the evenly cut stones. A remarkable feature of the masonry is the masonry of the curved walls, all of which are quite plumb and regular.

The walls of the cliff-houses were covered with colored sand, but few showed designs sculptured on the component stones as is the case in this structure. Figures were found incised both in stones of the walls themselves and on those which had fallen from them. As a rule, the designs are geometric in form, resembling those found on painted pottery from other ruins. Among the cut figures represented is a ladder leaning against a wall, an outline of a T-shaped door surmounted with a cross, a plan of a masonry wall, a representation of flowing water, tracks of birds, and various geometrical figures. All the loose stones so ornamented have been carefully collected and cemented together in a place where they may be seen by the visitor. They are regarded generally as very primitive steps in mural sculpture.

Set on a cornerstone outside the building at the southwest corner are the remains of two short walls evidently intended to inclose a figure as a shrine. On the upper surface of the cornerstone is the fossil imprint of the leaf of a palm, the radiating ridges of which resemble closely an ancient symbol of the sun and seem to indicate that this was the sun shrine of the temple. Enclosed on three sides, it opens to the west, and on the autumnal equinox (September 21st) an observer seated on this fossil at sundown beholds the sun sinking below the horizon directly in front.

One reason that it has been difficult to decide definitely the original purpose of this building is that it

was never completed. Some of the theories advanced by visitors during the first part of the work on the ruin suggest its possible use as a domicile, a fort, a prison, or a mission, but all these suggestions, of course, have been dismissed. It was certainly not a habitation; the rooms are without windows, and they lack fireplaces; no traces of smoke appear on the walls, and there are no remains of débris, household implements or other objects which would indicate the habitation of this structure, and, moreover, it cannot be proved that there were ceilings or roofs. Dr. Fewkes feels certain that this house under the twin cedars was a ceremonial building on account of the evidences of unity in its construction and the existence of a preconceived plan before the erection was begun. There is nothing in the form of the ruin to indicate haphazard construction or the addition from time to time of extra rooms, as was the case in nearly all cliff ruins in the Mesa Verde Park. Only one purpose could have dominated and united the several clans of the primitive society which co-operated to erect the building, and that was a religious one. Two facts at least are easily interpreted in connection with religious rites, which would otherwise be without significance. The first is the shrine on the southwest corner, and the second, the presence of the three massive circular-walled rooms, which imply the execution of secret rites accessible only to the initiated. Doubtless the occupants of the neighboring cliff-houses constructed this building, for trails leading down to the cliff and across the canyons to their dwellings may still be seen.

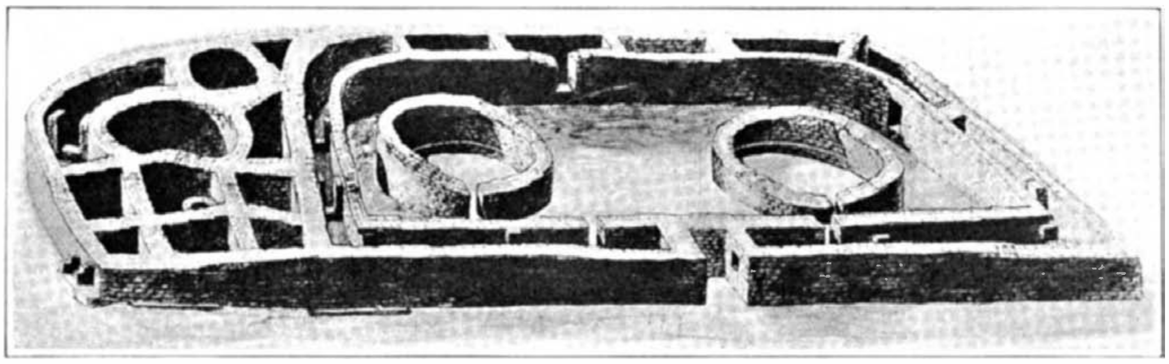
Dr. Fewkes states that nearly every one of his visitors asked the age of this ruin, how long it took to build it, and when it was deserted. Naturally, it is difficult to estimate the age of the structure. Judging from the annual rings the older cedar tree growing in the soil on the top of the highest wall is at least 360 years old, and probably began to grow about the year 1540, when Coronado first entered New Mexico. But how great an interval elapsed between this date and the time when the walls began to fall and to form the mound on which the tree grew, and how long before that the walls were laid, no one can possibly tell. It has been estimated that 250 years elapsed between the time the walls were built and the time the tree sprouted, thus carrying the construction of the building back to about 1300 A.D.

In order to preserve this monument of early civilization, great pains have been taken in its repair to prevent injury by the elements or by vandals, for though it is difficult to realize, many individuals in search of pottery and other small objects do not scruple to damage architectural remains that their collections may be augmented. In this ruin the ethnologist has not only excavated the earth and rock, but capped the tops of the walls with cement, leaving them in a state of good repair. From now on the employees of the Interior Department will see to it that everything remains just as it is. Protected from future harm under the watchful eyes of the keepers, this grand old ruin will remain intact for posterity.

It is hoped that the excavation and repair of other ruins will be carried out during the next season. Mesa Verde is unique in its educational importance, and is destined ultimately to become a Mecca for all students of the prehistoric in the Southwest, as well as an interesting example to all visitors who wish to see the best preserved buildings of pre-Columbian times in our country. The recent work has added a new architectural type to the park, and it is believed that two or more new styles of buildings await the pick and shovel of the investigator.

In order to facilitate access to the Sun Temple an automobile road has been constructed around it, so that visitors can alight near the walls of this newly discovered ancient temple in a far different manner than did the worshipers six hundred years ago.

Dr. Fewkes's work is invaluable; the officials of the Interior Department and the Smithsonian Institution are to be congratulated. The average citizen of these United States is also to be congratulated, in that his Government has recognized the importance of preparing for his observation and study these graphic illustrations of the history of his country. But it still remains for Mr. Average Citizen to avail himself of the opportunities afforded by this new class-room and learn thereby what he may. The Government of our genial Uncle is offering a new slogan for "See America First;" it is this: "Learn the History of Your Country from Your Country Itself." The first lesson in antiquity is now open in Mesa Verde National Park.



Perspective drawing of the restored Sun Temple, showing various rooms, entrance and the shrine at lower left corner.

Automatic Looms

In comparison with a hand loom the power loom is an automatic machine, the three essential weaving operations—the division of the warp threads, the propulsion between these threads of the shuttle carrying the weft and the beating-up of the inserted weft thread into its correct position—all being automatically performed in addition to other auxiliary motions necessary to effect a large production of fabric. But the ordinary power loom is not provided with mechanism to effect a replenishment of weft, and consequently has to be stopped periodically in order that the attendant weaver may perform this operation. A shuttle carrying an ordinary cop or bobbin of weft thread will run for a period of approximately 4 to 6 minutes—according to the fineness of the yarn—before becoming exhausted. It follows that every 4 to 6 minutes the weaver has to stop the loom and replenish the weft. Apart from the fact that the starting and stopping is detrimental to the yarn threads, the point to be considered is that the weaver is thus taxed to her utmost capacity to tend 4 looms, and the threatened scarcity of efficient weaving labor in Lancashire necessitates serious consideration of the available mechanical resource to combat such scarcity.

Automatic looms can be broadly divided into two distinct types—the weft replenisher and the shuttle changer. After considerable experience of both types the writer agrees with Mr. Oscar Hall, who recently read a paper on "The Coming of the Automatic Loom," that the only possible type is the weft replenisher. A loom runs at anything from 180 to 220 picks a minute; that is, the shuttle traverses a space of more than 4 feet 6 inches 180 to 220 times a minute, and for a small but appreciable time is stationary in one or other shuttle box, between traverses. The velocity of the shuttle is therefore very considerable, and to eject it bodily, while the loom is running at this high rate of speed, is very detrimental to the shuttle, while to force into the shuttle box a fresh fully-loaded shuttle during the momentary rest of the exhausted shuttle in the box is conducive to inefficiency of operation and breakage of parts. The work to be accomplished in changing a shuttle at such a high rate of speed is too heavy and severe on the shuttle and the mechanical parts to insure success.

Mechanism to effect the replenishment of an exhausted shuttle by forcing a full cop or bobbin of weft yarn into the shuttle presents fewer difficulties. Two methods are open to the loom maker. He can take a loom of ordinary type and apply to it auxiliary mechanism which will effect the replenishment of the weft, but which is an entirely independent piece of mechanism; or he can redesign the loom and add new mechanisms forming an essential part of the design. Other motions besides those for weft replenishment are applied, and the loom becomes a complete weaving machine, efficient in its fabric producing operations and further so designed that the weft replenishing operations are facilitated and assisted.

The loom thus becomes a more perfect piece of mechanism, but as a consequence the cost is advanced. When Northrop looms were first introduced into this country their cost was £40; nowadays their cost is £30, while a good, plain loom can be obtained for £10. There are a number of looms that may be considered as complete automatic looms, but the Northrop and the Steinen may be mentioned as being the best known in this country. To these must be added the Stafford in the United States.

Attachments or auxiliary mechanism that will render an ordinary loom automatic can be applied for—in some cases—a cost of £2. There are examples of mechanisms of this class which are quite efficient, and although the loom as a whole is not such a sympathetic combination as a completely designed automatic loom, good results are secured. The difference in first cost is, however, very considerable. Even provided that new looms are purchased the cost with attachment would be at the outside £12, against the £30 for the Northrop, equivalent in a shed of 500 looms to an increased first cost of £9,000. But in a considerable number of cases manufacturers have looms which are good profit-earning machines, and even though they may have been running for a number of years, they are still of value and have many more years of life in them. To throw out such looms would mean a loss which must be considered, but they can be fitted with the auxiliary mechanisms at a small cost. It is a debatable point which course will be eventually followed.

It must be remembered that the time available for inserting the fresh cop or bobbin of weft yarn is very short. In certain cases the looms are provided with a feeler, controlled either mechanically or electrically, which anticipates the exhaustion of the weft and operates the change mechanism. Such mechanism is comparatively simple, and consists essentially of a "pusher" lever which is operated from some moving part of the loom—preferably the part carrying the beating-up device and shuttle boxes—and impinges against a cop or bobbin of weft yarn carried in a magazine, forcing it into the shuttle. As the fresh bobbin is forced into the shuttle the empty one is forced out and falls into a receptacle placed for the purpose. In the complete looms—and also in combination with certain attachments—several parts are added to facilitate the change. When a feeler is dispensed with the ordinary weft fork action of the loom is utilized to bring the changing mechanism into action.

As regards the value of all this added mechanism it would appear that up to the present the only effective gain is in the reduced amount of weaving labor required, as no definite figures have been published which indicate that the automatic loom increases the production per loom, although it does so per weaver. On Northrops one weaver can attend to 24 looms, while on the Steinen it is claimed that three operatives can efficiently look after 100 looms.

It may safely be said that the power loom of the present day is by no means a perfect piece of mechanism, and the application of weft replenishing mechanism will not eradicate its faults. Electricity and compressed air have been utilized to a small extent in connection with the Steinen loom, but the possibilities of an extended use of these powers in connection with loom construction and in the operation of loom parts appear to be very considerable. The present extremely uneconomical, negative, inefficient operation of picking, or throwing the shuttle, is likely to be superseded by a method of pneumatic picking. It is hardly conceivable that with the enormous developments taking place in every branch of science and industry the power loom will be allowed to remain in its present state.—*Engineering Supplement of the London Times.*

Sand Filters

It is well known that there are certain obscure points in the action of sand filter basins such as are employed in large waterworks, as regards the exact cause of the purifying and other action of the filter upon water passing through it. For instance, it is recognized that the organic membrane formed on the surface of the sand is one of the principal agents in the action. A Paris scientist, M. Maquenne, treats of this subject, referring especially to the fact that the amount of oxygen dissolved in the water leaving the filter is superior to what the incoming water contains. He considers that the reason for this effect does not lie in the fact that the filter was left for a long period in free air before the operation, as has been maintained, and he claims it is due to the presence of a membrane of organisms and algae on the surface of the sand. By assimilation due to the action of chlorophyl, the organisms saturate the water with oxygen. This membrane is the most active part of the filter, and it is only when it is formed, i. e., 4 or 5 days after starting, that the present effect is most marked and the filter has its maximum action, but this action decreases in time, so that after a few weeks the filter needs to be stopped and cleaned.

The Future of Ship Propulsion*

A Comparison of Various Systems of Power and Arrangements of Propellers

SINCE the days of the Romans, whose motto was that the three essentials to civilization were roads, more roads, and "still some," the close connection between cheap transport and the amenities, and, indeed, the necessities, of society has been realized, but much more clearly by the engineer and business man than by the public at large. In fact, ignorant publicists have been known to aver that the masses of the people have derived no benefit whatever from the work of the engineer, which has made it possible to transport meat some 8,000 to 12,000 miles, from New Zealand or the Argentine, and enables wheat grown west of Winnipeg to find its way into British silos. One hundred and fifty years ago 20 miles was not far from the limit beyond which the cheaper kinds of food could not be profitably conveyed by land, and though sea freights were much cheaper than land carriage, imported goods could not find their way far from their port of entry, save at rates prohibitive to all but the more costly class of commodities. The contrast with the present day is extraordinary, and though much, no doubt, yet remains to be done, it is most unlikely that any equally striking step forward can be made in the years to come. All we can look for is a steady step-by-step advance, and this applies with special emphasis to the problem of marine transport. In normal times this is extraordinarily cheap, but there is nevertheless a sustained endeavor to reduce still further operating costs. A few years ago there was a feeling somewhat prevalent that for marine propulsion the future lay with the Diesel engine, but further experience has proved that this type of motor is desirable only in somewhat special circumstances. Indeed, some engineers claim that even where oil fuel is available, it is now more profitable to use this under boilers than to install Diesel engines even of moderate size. Of course, in the case of very large powers, the Diesel engine is admittedly inferior, all things considered, to the steam-turbine. It is, nevertheless, undoubtedly of interest to note that Messrs. Burmeister and Wain are reported to have received orders for motor-ships which will keep them occupied till the end of 1921. Included in the list are six ships, of 12,800 tons dead weight, which are to have motors of 5,300 horse-power.

The very high economies realized with the steam turbine in land installations have naturally initiated inquiries into how far similar results may be obtainable at sea. A few years ago engineers had by no means abandoned the hope of devising an efficient high-speed propeller, thus abolishing the clog which the standard type had established on the speed of rotation needed to secure an efficient turbine. This anticipation appears now to have been abandoned, and, indeed, the recent elucidation of the propeller theory, which has been effected by those interested in aerial navigation, gives reason for belief that the idea is little likely to be resuscitated. All hopes are now centered upon the introduction of some kind of reduction gear, mechanical, electrical, or hydraulic, between the turbine and the propeller shaft. The first-named has the advantage of a very high efficiency. The electric and the hydraulic systems are less efficient *per se*, but have some compensating advantages. Moreover, the claim is made that they will permit of the use of a more economical steam plant than can be adopted with mechanical gears.

A most instructive comparison of the relative advantages of different methods of propelling a 21,000-ton 19¼-knot liner is given in a paper recently read before the Institution of Engineers and Shipbuilders in Scotland by Mr. James Dornan, and a consideration of which we have deferred until it had been discussed fully at the Institution. Papers of this kind are exceedingly valuable, and necessitate a very large amount of labor, of which the outcome is often merely the addition of a few rows of figures in the tabulated results. The compact manner in which the outcome of toilsome calculations can thus be expressed fails to draw due attention to the great care and thought that have been expended in the compilation.

The worth of such a paper is by no means dependent upon the absolute precision of the assumptions necessarily made in the course of the work. It was a politician, concerned, like his kind, for his consistency, who formulated the view that you should never prophesy unless you know. If this motto were adopted by engineers, the world would be at a standstill, since all improvements necessarily involve some measure of vaticination. Certain assumptions have to be made, as to the sufficiency of which only experience can decide. In any paper forecasting the future certain risks must accordingly be taken, and as no one engineer has a universal experience, his particular assumptions may not prove acceptable to every individual of his audience, each of which has his own special experience. Indeed, this circumstance adds to the value of papers such as we are considering, as in the discussion each specialist is able to support his own claims.

The two main assumptions made by Mr. Dornan were that tooth pressures and pitch-line speeds have already reached their limits in large marine gears, and that highly superheated steam cannot be used in installations in which reversing turbines are employed, and it was on these points that the criticism of his paper largely centered. On the above hypotheses Mr. Dornan has worked out comparative results for seven different types of propelling machinery suitable for a liner measuring 600 feet by 72 feet by 27 feet draught, displacing 21,000 tons, and having a service speed of 19¼ knots. His results are summarized in the table below.

A noteworthy point is the excellent showing made by the reciprocators using superheated steam. These engines are, it will be seen, credited with a better performance than the corresponding turbines, which is attributable to the higher superheat used. In this connection it may be observed that had high superheats come into general use for reciprocating engines twenty-five to thirty years ago, the task successfully carried through by Sir Charles Parsons might well have proved impossible. His turbine is essentially a big-unit machine, and his ability to develop it in the days of small units was largely due to the relatively high steam consumption of the reciprocating engines then available. This defect has, in the outcome, been to the advantage of the world, as the experimental work necessary to the successful development of the Parsons turbine could never have been financed if it had had to be carried out on large units.

The high position occupied by the hydraulic gear in Mr. Dornan's table is due, in the first place, to the ratio of reduction being suitable for this system, which is well known to be inapplicable for speed ratios greater than some 6 to 1, and, secondly, to the high superheat used. With a propeller speed of 200 revolutions per minute, it is, moreover, credited with the same propeller efficiency as the geared turbine machinery, in which the speed is 160 revolutions per minute. Had this figure been increased to that adopted for the hydraulic gear, a smaller or more efficient turbine could have been used. In Mr. Dornan's view, however, an alteration of this kind would have involved dangerous tooth-pressure and pitch-line speeds.

It is on this point that criticism naturally fixed. Experience with high-speed gears is still somewhat limited, and many more breakages must occur before engineers can be certain that the limit of safety has been reached. With the relatively large pitches used in some of the earlier plants, a breakage occurred in one case with a tooth-pressure equal to about 1,100 pounds per inch width of face. The pitch in this case was about 4/5 inch, and it is understood that the teeth were of unsuitable form. According to Mr. J. H. Gibson, the standard pitch for large marine gears is now 0.583 inch, and the wheel-teeth have very short addenda. It is understood that in certain ships now building the gear-driven propeller shafts are to transmit nearly twice the power per pinion specified by Mr. Dornan. It is to be hoped that full data as to these remarkable installations will be available at a later date, so that comparison may be made with the figures brought forward by Mr. J. H. Macalpine in his most interesting contribution to the discussion on Mr. Dornan's paper. Mr. Macalpine claims many advantages for the method of mounting gears in a floating frame; but these claims have not, so far, been admitted by British engineers, who, in general, are of opinion that, with accurately cut teeth of suitable shape, frames of the type in question are superfluous, and the strength of their conviction is well evidenced by the remarkable sets of gears just referred to. The idea embodied in the floating frame is that the pinion shall be located by the teeth of the gear rather than by fixed bearings. At first sight, however, any self-adjustment of the frame to compensate for errors in the teeth would appear to be impossible, owing to the very high speed of the pitch line and the considerable inertia of the pinion and its frame. If the error in question were confined to a single tooth, it would seem that this conclusion would be indefeasible; but the experiments of Sir Charles Parsons do undoubtedly put rather a different aspect on the matter. He found by actual measurement that the errors in well-cut gears were periodic in character. This observation much improves the case for the floating frame, since such periodic errors would presumably follow approximately a sine law. The frame therefore would not have to adjust itself violently and instantaneously, as it would with the error confined to a single tooth or a single region of the wheel, but would gently oscillate from a position in which the positive errors in the teeth were a maximum to that in which they were a minimum. The change of motion being made at these maximum and minimum values would greatly minimize the effect of the inertia of the pinion.

As is well known, Sir Charles Parsons solved the problem by abolishing the periodic errors. From Mr. Macalpine's remarks, it would seem that the floating frame has proved an equally effective solution, and the figures he gives are of the greatest interest, and indicate that the weights and dimensions assumed by Mr. Dornan as necessary when mechanical gearing is introduced may be very materially reduced. Mr. Macalpine states that the Westinghouse Machine Company are making gears for two foreign warships, each to be fitted with machinery developing 22,000 horse-power.

COMPARATIVE DATA OF DIFFERENT TYPES OF PROPELLING MACHINERY FOR A STEAMSHIP 600 FEET LONG, 72 FEET BEAM, 27 FEET DRAUGHT, 21,000 TONS DISPLACEMENT, AND 19¼ KNOTS SPEED.

Design	A.	B.	C.	D.	E.	F.	G.
	Two-Shaft Quadruple Engines.	Four-Shaft Direct Turbines.	Two-Shaft Quadruple Engines. (Superheat.)	Four-Shaft Direct Turbines. (Superheat.)	Two-Shaft Hydraulic Gears.	Two-Shaft Mechanical Gears.	Two-Shaft Turbo-Electric Gears. (Ljungström.)
Number of shafts	2	4	2	4	2	2	2
Revolutions per minute (propeller shaft)	85	290	85	290	200	160	85
Indicated horse-power	21,650	....	21,650	....	....	....	....
Shaft horse-power	....	21,800	....	21,800	21,300	21,350	20,000
Revolutions per minute (turbines)	....	290	....	290	1,000	1,800	3,000
Working pressure, lb. per sq. in.	210	200	210	200	200	200	200
Superheat, deg. F.	Nil	Nil	200	100	200	100	260
Vacuum, in.	27	28	27	28	28½	28½	28½
Steam per hour—main engines, lb.	274,400	258,400	235,000	238,000	211,050	220,200	167,240
Steam per hour—auxiliaries, lb.	43,600	43,600	36,000	38,000	35,000	35,000	29,000
Coal per horse-power hour, lb.	1.47	1.385	1.257	1.292	1.205	1,218	1.032
B. Th. U. per horse-power hour, lb.	20,600	19,400	17,600	18,100	16,900	17,050	14,500
Economy over Design A, p.c.	....	5	14½	11½	19	18	35
Boilers — Double-ended	6	6	6	6	6	6	4
Boilers — Single-ended	4	4	3	3	2	2	3
Heating surface, sq. ft.	52,000	52,000	48,750	48,750	45,500	45,520	35,750
Grate area, sq. ft.	1,232	1,232	1,155	1,155	1,078	1,078	847
Weight of machinery, tons	3,675	2,965	3,610	2,900	2,445	2,605	2,310
Weight of machinery plus coal, tons	6,403	5,557	5,946	5,316	4,653	4,837	4,086
Saving in machinery space, ft.	....	15	18	21	60	51	72
Cubic capacity gained, cub. ft.	....	18,100	21,200	24,250	64,900	56,970	80,600
Coal used per annum, tons	51.150	48,600	43,800	45,300	41,400	41,850	33,300
Extra dead weight carried yearly, tons	....	20,304	10,968	26,088	42,000	37.584	55,608
Value of coal saved, £	....	2,550	7,350	5,850	9,750	9,300	17,850
Value of extra dead weight, £	....	14,213	7,678	18,261	29,400	26,308	38,925
Total saving, £	....	16,763	15,028	24,111	39,150	35,608	56,775
Cost of ship, £	650,000	650,000	668,500	670,500	673,000	672,000	678,000

In all the comparisons made, A is taken as the standard of reference.

* *Engineering.*

The guarantees with dry saturated steam at 225 pounds per square inch are as follows:

	Consumption per Shaft Horse-power. Lb
Full power	10.8
80 to 85 per cent	10.5
25 per cent	11.5
15 per cent	12.8

At 15 per cent of full power, corresponding to about half speed, the consumption per shaft horse-power is only 18.5 per cent greater than at full power. He states that for the case taken in Mr. Dornan's paper, where 5,100 horse-power are to be transmitted per pinion, the following proportions would suffice: Pinion diameter, 8 inches; wheel diameter, 148 inches; revolutions per minute of pinion, 2,500; revolutions per minute of propeller shaft, 135.1. The length of the pinion would be 4 feet 8 inches, as compared with the 7 feet 6 inches or 8 feet assumed by Mr. Dornan. Mr. Macalpine further observes that the modifications he suggests in Mr. Dornan's figures would enable the size of the turbines to be reduced, so that the mean diameter at the low-pressure end would be only 4 feet 7 inches. We are inclined to believe, however, that this change would give a steam-way somewhat more restricted than is desirable, unless it be intended to use double-flow turbines. For a 28½-inch vacuum, the mean diameter in inches of the last row of blades should not be less than about 0.63 $\sqrt{\text{S.H.P.}}$, or, say, 64 inches. Of course, there is no absolutely fixed rule in this matter, since different engineers have different views as to the loss permissible by "carry over" to the exhaust.

By taking advantage of the improvements now realized in mechanical reduction gears, Mr. Macalpine concludes that the advantages claimed in Mr. Dornan's paper for the turbo-electric drive are transferred to its rival, which would occupy a length 16 feet 4 inches less than the turbo-electric drive, in place of the 21 feet more with which it is credited in the paper. The turbo-electric installation described by Mr. Dornan has a special interest of its own. It is proposed to use Ljungström turbines running at 3,000 revolutions per minute, and supplying current to electric motors which drive the propeller shafts through mechanical reduction gears. One reduction of speed is effected electrically, and the remainder by the mechanical gears, the advantage of the system being the large reduction ratio practicable without the reduction in power factor which would be involved in the use of multiple motors.

A Ljungström turbine capable of developing 5,000 kilowatts at overload has already been constructed, and undergone its preliminary tests. The highest load reached in these was about 2,000 kilowatts, the steam consumption at this load being 11 pounds per kilowatt-hour, with a steam supply at 15 atmospheres absolute, and a superheat of about 280 deg. Fahr. The vacuum was extremely high, so that there would probably be no very great improvement in the water-rate when the output was doubled. According to the curves given in the *Teknisk Tidskrift* the anticipated consumption at 5,000 kilowatts is about 10.8 pounds per kilowatt-hour. In his paper Mr. Dornan has assumed that with turbines of 10,000 horse-power a water-rate of 7.5 pounds per shaft horse-power hour will be recorded, and has presumed that it will be possible to run the turbine at 3,000 revolutions per minute. The limit to the output of a Ljungström turbine at a given speed appears to depend on the critical velocity of the largest ring of blades. The output depends upon the length of this row, which must not be so great that its natural periodicity coincides with the rate of revolution of the turbine. The linear velocity feasible for this row of blades is, of course, fixed by the permissible centrifugal stresses. According to Mr. Konrad Anderson stresses of 16 tons per square inch are admitted in De Laval wheels, and a rough estimate of the size of the 5,000-kilowatt unit, illustrated in the *Teknisk Tidskrift*, conveys the impression that the centrifugal stresses in this machine are of somewhat the same order.

The advantages of the Ljungström system are most marked in the case of units of what are now considered moderate outputs. We gather from Mr. Dornan's reply to the discussion that the 5,000-kilowatt set above referred to has a "coefficient" of 300,000, which is remarkably high for a turbine of 5,000 kilowatts only. Even the great Chicago turbine has a coefficient of but 216,000. High coefficients can no doubt be obtained with axial-flow machines of moderate output at the price of introducing velocity compounded impulse stages at the high-pressure end, but it is not possible to attain in this way the efficiencies realizable with the "straight" reaction system. On this head Mr. Macalpine's criticisms of Mr. Dornan's paper seem beside the point, as it will never be possible to reach with disk and drum machines the same limit of efficiency attainable with the straight reaction type. When constructed on the axial-flow principle, however, any close approach to the theoretical limit is commercially impracticable in the case of small machines, but this difficulty is surmounted in the Ljungström turbine, with which remarkable results have been secured in the steamship "Mjölner" with a plant developing 843.4 shaft horse-power.

It will be noted that much of the advantage claimed for Mr. Dornan's electrically geared drive is to be attributable to the high superheat of 260 degrees, while 100 degrees superheat is all that he allows to the geared turbine. No doubt there have been difficulties met with in using superheat at sea with existing patterns of marine turbine. In fact, at the last meeting of the Institute of Metals, Admiral Oram observed that they had adopted superheat but sparingly in the navy, and that he personally should prefer to be without it entirely. This view, which is founded on practical experience, is the more noteworthy in that the superheat has in all cases been very moderate, and the turbines to which it was applied of a type generally presumed to be free from troubles due to differential expansion and the like. On the "Mjölner" a superheat of 190 deg. Fahr. has, we understand, been used and has given no trouble during the many months the vessel has been in service. Of course, the Ljungstrom type is particularly well adapted to the use of high temperature steam. It is almost perfectly symmetrical, so that it must be nearly free from distortion by temperature changes. Moreover, in parts where the temperature is high the steam velocity is low, while in disk and drum machines high temperatures and high velocities are associated together, which is no doubt largely responsible for such trouble as has been found in securing a satisfactory metal for the blading. It would, however, be rash to assume that these difficulties are insuperable, particularly if it is merely on account of the reversing turbine that Mr. Dornan has limited the superheat to 100 deg. Fahr. in proportioning his geared turbine. In this connection it is of interest to note that the builders of the Ljungström turbine are themselves experimenting with all gear drives, thus suppressing the losses necessarily associated with the electrical plant. Some of this loss might, no doubt, be recovered by a greater use of current to drive the auxiliaries now commonly actuated by "steam eaters," and in view of the very large proportion which the auxiliary steam frequently bears to that entering the main propelling machinery, some satisfactory method of economizing auxiliary steam is badly desiderated.

As to the relative advantages of mechanical and electric drives, some figures contributed by Mr. Macalpine should be put on record here. He stated that very careful comparative estimates of the weights involved for a 10,000 horse-power twin-screw ship had been got out by the Westinghouse Company.

Type of Machinery.	Machinery Weights (exclusive of Boilers and Auxiliaries). Lb.
Geared turbines	274,000
Turbo-electric drive (geared generators)	304,000
Turbo-electric drive (direct-connected generator)	423,800

Mr. Macalpine further stated that an estimate made for a gear-driven 28-knot battleship developing 64,000 horse-power showed that the total weight of turbines, gears, and thrust-blocks was but 212 tons, the propeller speed being 420 revolutions per minute. It is proposed to use thrust-blocks of the Michell (Kingsbury) type, of which 22 are now at work in America under loads ranging from 350,000 pounds up to 550,000 pounds, in addition to many taking smaller thrusts. In such ships as discussed in Mr. Dornan's paper, the use of these blocks would save, he states, at least 8 feet of length.

Visual Pattern-Discrimination in the Vertebrates A Demonstration of the Dog's Deficiency in Detail-Vision*

By H. M. Johnson

Some years ago the writer made some lengthy experiments[1] on the rate and methods of acquiring skill of blind, temporarily blind, and normal dogs, and accumulated quite a mass of evidence that in learning to make quite complicated adjustments the dog makes but little use of vision. There was also some evidence that in uncontrolled behavior dogs react to many ordinary objects as if the latter were not visually perceived. These data emphasized the interest of the question as to the kind and degree of vision which the dog may have.

In the year 1911-12 I attempted to train a dog by the discrimination method of Yerkes and Watson to discriminate between a circle 6 centimeters in diameter and its approximately equivalent square. In the preliminary training I presented a 4 to 1 difference in brightness (which in this case made a 4 to 1 difference in luminous intensity) in addition to the difference in outline of the two objects. Under these conditions the dog established discrimination in 1,000 trials. When the two fields were equated in brightness he ceased to discriminate, and showed no preference for the positive field in 600 additional trials.

In the present work I used a pure-bred English bull-terrier with two emmetropic eyes. The first attempt made was to train him by the Yerkes-Watson method to choose a food-box indicated by a field covered by coarse stripes, and to avoid, under penalty of an electric shock, a food-box indicated by a field of uniform brightness. The two fields were, of course, interchangeable with reference to the food-boxes, and were equal in area, outline, and mean brightness, the latter being 12.2 candles per square meter. The animal was required to choose at a minimal distance between test-object and eye of 60 centimeters. He failed to learn the problem in 1,200 trials, although the pattern on the "positive" field was quite coarse. A monkey and two chickens trained under comparable conditions established a perfect habit in from 200 to 400 trials each.

I then presented a difference in area in addition to the difference in distribution of brightness over the fields, and the animal acquired a perfect habit very quickly. Control tests showed that the difference in pattern was ineffective, as the animal's responses were not affected in accuracy by eliminating that difference. The effective difference in area was between 2.25 to 1 and 1.44 to 1. Since the two fields were of equal brightness, this difference in area resulted in a corresponding difference in luminous intensity. I now made the brightness of the test-field inversely proportional to their areas, and the animal immediately ceased to discriminate. This indicated that his discrimination had been based on difference of luminous intensity alone.

It now became necessary to ascertain and consider certain structural characteristics of the dog's eye considered as an optical system. There is a mechanism for accommodation as in the typical mammalian eye. According to Freytag, however, the refractive index of the lens is almost exactly the same as that of the fluid media. All the refraction undergone by an incident beam in such an eye must, therefore, take place at the cornea. Change of the radius of curvature of the lens would not in itself change the focal length. The eye is set for a single focal distance, and only objects at a given distance may be imaged on the retina. In this dog, parallel rays, or rays proceeding directly to the eye from an object 20 feet or more away, are brought to a focus on the retina. In the next experiment each test-object was mounted in the principal focus of a good projection lens. Under the experimental conditions a sharp image of the test-object was formed on the retina, no matter where the dog's eyes were placed in the cone emerging from the lens.

In this experiment the two fields were 6.2 candles per square meter in mean brightness, circular in form, and 6 centimeters in diameter. The positive field was covered by a system of alternate dark and bright stripes, each member of which subtended a visual angle of 33 feet 32 inches. The negative field was of sensibly uniform brightness. The pattern on the positive field may be compared to that of a plank fence in which the planks are 6 inches wide and 6 inches apart, viewed at a distance of 50 feet. The dog did not learn to discriminate between these two fields and did not show a tendency to improve in 500 trials. Under the circumstances I regard his failure as conclusive evidence that he is unable to distinguish quite gross details in visual objects. Since the experimental conditions insured the formation of a sharp image on the retina, we must attribute his failure to relative insensitivity of that organ to distribution of brightness over it. There is no fovea in the dog's retina, the sensitive area is indefinite both in form and extent, and there are numerous branching of opaque nerve-fibers which must be regarded as blind spots. As is suggested above, if accommodation is not impossible, its range must be extremely small. There is a tendency to gross errors of refraction, varying widely in different individuals. For many of them the retina can never be stimulated by a sharp image. It should not be inferred from the above that the dog's eye is a useless organ, for such a retina, like the peripheral region in the human retina, seems to be quite sensitive to movement of visual objects. This is probably the most important form of visual sensitivity which the dog possesses.

The structural characteristics of the dog's eye obtain among other carnivora and among ungulates and rodents. The foregoing results, considered in the light of comparative anatomy, suggest that we are not justified at present in attributing detail vision to many other mammals below the primates.

* *Journal of the Franklin Institute.*

[1] Johnson, H. M.: "Audition and Habit-formation in the Dog," Behavior Monograph No. 8. Cambridge, Mass., Henry Holt & Co., 1913.

Great Electro-Magnets—II*

Wonderful Instruments Proposed for the University of Paris

Concluded from Scientific American Supplement No. 2105, Page 300, May 6, 1916

Fig. 12 presents the most recent model of the Weiss electro-magnet, constructed at the Oerliken shops for Becquerel. It is no larger than previous models of the same makers, in fact, the yoke was cast in the same mold, and the cores (including the central tube of the coils, which is of iron) are of the same diameter, 17.5 centimeters. But it has the benefit of two improvements recently made (ferro-cobalt and winding), which give it marked advantages. Measures of the field of this instrument made at Zurich by Weiss, Picard and Fortrat have determined its field in functions of the number of ampere-turns, and from this it is to be seen that the rapid rise is quickly attained, followed by a slow rise, and in passing from 100,000 ampere-turns to 200,000, the field is augmented 1,800 gauss. A machine with only half as many turns and half as much copper gives nearly the same field, and there is the additional advantage besides this economy in working in a field where the iron is saturated in that the field remains uniform, and there can here be 2 per cent variation in the current without greater variation in the field than one thousandth. Other curves (Fig. 14) show the advantage of the ferro-cobalt, which permits of obtaining the same fields with much less cost, and from them it is evident that to increase the fields to be obtained in a given air-gap is difficult with such form of electro-magnet. The gain obtained in the increase of excitation is due almost entirely to the direct field of the coils, which is of the order of 2,000 gauss for strong excitation.

Considering the enlargement of the electro-magnet, the diameter of one meter for the cores being the figure, it is possible to predict results by processes of multiplication of present units. Such an instument would for one item require not less than 68 tons of copper, although in practice there would be some reductions from the computed figure.

Prof. Cotton next outlines the details of the Weiss constructions, prefacing his description with some mathematics and presenting the projected hundred-ton electromagnet which has been planned by the Oerlikon shops. (Fig. 15 shows the disposition of the parts.) The yoke is computed to weigh 60 tons, but despite its form, an open rectangle, it ought to be able to sustain without sensible deformation the strain of 120 tons which would be applied to it for the maximum. The cores are to be movable within the central cylinder of 90 centimeters, the diameter of the iron lining to the coils. They weigh 8.5 tons each but may be moved one at a time by means of a screw actuated by a 2 kilowatt motor. A truck of 9 tons will accompany the apparatus for placing the heavy parts and for changing the polar pieces, which are to weigh some hundreds of pounds each.

The conductor as planned is a tube of copper, square in section, a form most advantageous in point of space required, although somewhat costly. The hole in the tube is to be round as offering the least resistance to the flow of liquids. Each of the coils is planned to include ten sections held by five independent yokes. The winding is such that for a normal excitation of 500,000 ampere-turns the current density should be 1.4 amperes per square meter. The instrument should require only 50 kilowatts. The great amount of copper, about 40 tons, will make the machine itself rather costly, but on the other hand, the experiments are comparatively inexpensive.

* Translated and abridged from the *Révue Générale des Sciences Pures et Appliquées* by J. Ritchie, Jr., for the Scientific American Supplement.

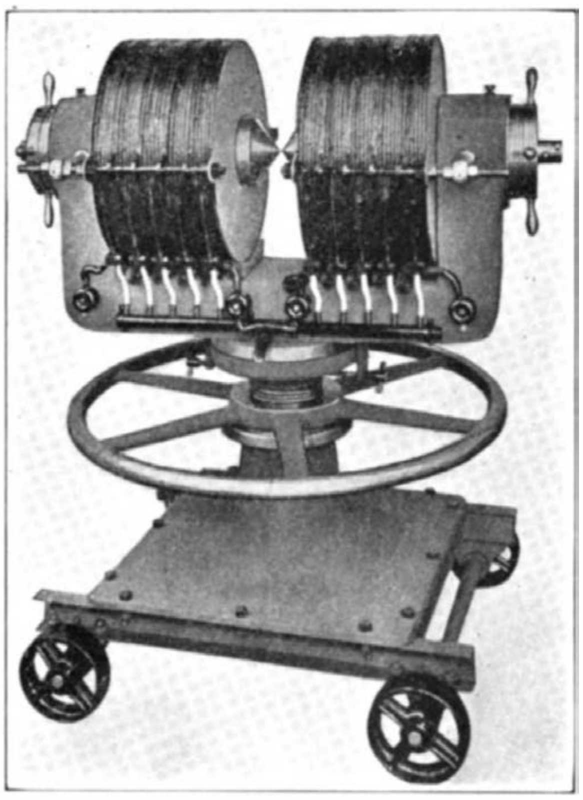


Fig. 12.—Weiss electro-magnet constructed for the Museum of Paris.

COMPUTED MAGNETIC FIELDS FOR THE GREAT WEISS ELECTRO-MAGNET WITHOUT POLAR COILS. (ASSUMED POWER 200 KILOWATTS; NORMAL POWER 50 KILOWATTS.)

Air Gap.		Field in Gauss.
Area in Millimeters.	Length in Millimeters	
3.0	2.0	70,100*
5.7	3.5	64,500*
	5.0	61,400*
	10.0	55,200*
17.2	5.0	58,000
17.2	10.0	53,000
	15.0	48,700
28.5	5.0	54,200
	10.0	50,700
	25.0	48,000
55.0	5.0	47,400
	20.0	41,750
	40.0	36,000
85.5	20.0	39,450
	40.0	35,600
	80.0	28,850
230.0	40.0	31,650
	100.0	26,200
	200.0	19,450
515.0	100.0	22,850
	200.0	16,970
	300.0	13,400
900.0	5.0	23,600
	200.0	7,420
	300.0	5,140

* Owing to minor uncertainties the figures thus marked are subject to an error of a few hundredths. It is assumed that ferro-cobalt is used in the polar pieces. For iron the three groups beginning at the top would be reduced 8, 7 and 6 per cent, respectively.

The computations show that under the normal excitation, 50 kilowatts, the mean current density will be only 0.83 ampere per square meter, the water should emerge from the circulation with a rise in temperature not greater than 12.5 deg. Cent. and three atmospheres of pressure may be employed.

If the amperage is doubled and 200 kilowatts furnished for the permanent excitation the elevation of the water will then be not more than 50 deg. Cent. and the gain in the field considerable, at least 2,000 gauss. This increase is obtained without modification in the instrument, and without minor changes in current having appreciable effect on the field.

With this greater excitation the accompanying table has been computed for related field and air gap.

The table shows that the principal advantage of the apparatus is in the great increase in the dimensions of the gap. The same fields have already been achievable, but in volumes that were 200 times smaller. In certain researches, among them rotary magnetic polarization, magnetic bi-refraction and the deviation of electrized particles, there will be enormous facility in the new constructions. Important questions like the retardation of magnetic bi-refraction hang on some such device.

There will be a gain of equal importance in what concerns the value of fields in very small gaps. One can conveniently make researches with fields of 50,000 gauss in gaps where it has before been possible to get only 30,000. With the smaller gap, 3 millimeters by 2 millimeters, 70,000 gauss may be obtained, and so small an air gap has hitherto rarely been usable.

If fields of 100,000 gauss are practicable it will be possible to increase the dimensions of fields still more. For that reason Weiss and Cotton have already thought out an apparatus with fields more intense.

The discussion now turns to another form of electro-magnet, that of Deslandres and Pérot, where the cylindrical cores are cast aside and are replaced by polar cones which are attached to a yoke of negligible reluctance. Further than this all the winding is about the poles. The coils are in a cavity in the yoke (Fig. 16), and consist of ribbons of naked copper of 0.3 millimeter thickness rolled like the hair spring of a clock. The refrigerating liquid is gasoline cooled to about —25 deg. Cent., which is not only the cooler but the insulator. The liquid flows between the turns of the metal in a direction parallel to the axis of the coil. This coil has been able to support a current of 1,900 amperes, so that the little machine, weighing only 35 kilogrammes, has been able to absorb a power of 76 kilowatts. Under these conditions with an air gap of 2 millimeters by 1.7 millimeters, with polar pieces of ferro-cobalt, the field attained has been 50,500 gauss.

The experiments have been very interesting for they constitute the first trial at applying considerable electrical energy to a coil of little volume. The application of cold diminishes somewhat the performance of the instrument, but it permits of increases in the values of the mean current density.

An improvement came to light when it was proposed to build a larger instrument, for it was found that these investigators were cooling with unrefrigerated running water, which has a resistance of about one billion times that of copper or silver. It is believed that water will insulate without establishing electrolysis. (Fig. 17 will give an idea of an improved form of this type of electro-magnet.) Pérot proposes to construct three such instruments relatively proportioned as 1, 2½ and 5 and for them the following figures have been computed.

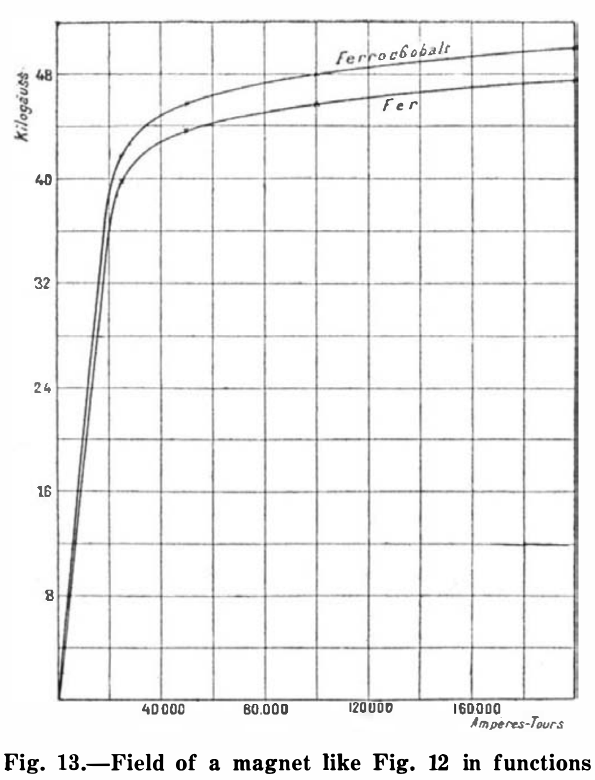


Fig. 13.—Field of a magnet like Fig. 12 in functions of ampere-turns.

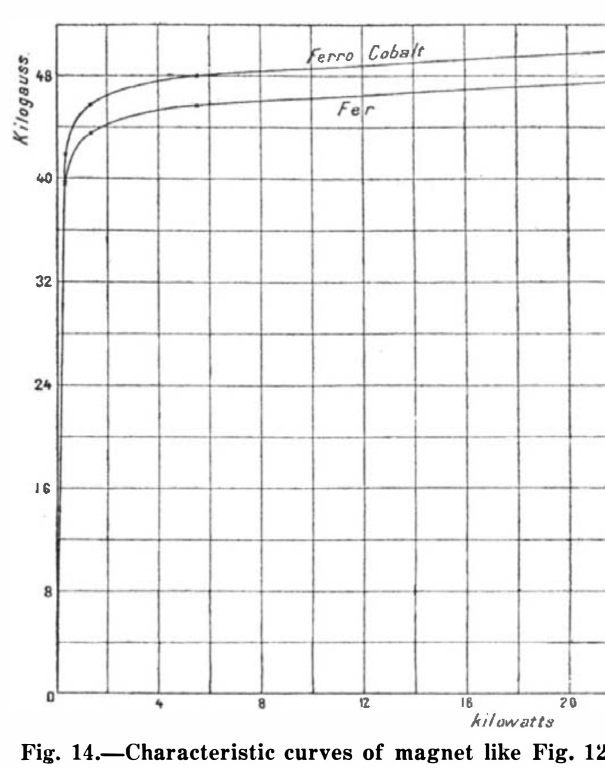


Fig. 14.—Characteristic curves of magnet like Fig. 12 in functions of energy used.

COMPUTATIONS BY M. PEROT FOR THREE SIZES OF ELECTRO-MAGNETS WITH POLAR COILS.

Type.	Diameter of Hole.	Air Gap.	Field in Gaùss.	Kilowatts.
1.0	30	3.0 by 1.7	50,000	21.5
	30	3.0 by 1.7	75,000	226.0
2.5	75	7.5 by 4.25	50,000	51.7
	75	7.5 by 4.25	75,000	527.0
	75	7.5 by 4.25	100,000	1629.0
5.0	150	15.0 by 8.5	50,000	101.7
	150	15.0 by 8.5	75,000	1019.0

In discussing the possible future of such instruments Cotton notes that they can gain high fields in the neighborhood of 100,000 gauss with an initial cost that is low, the apparatus of the largest model being but a few tons

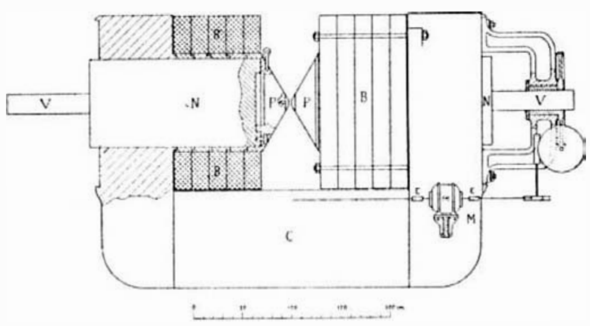


Fig. 15.—Section of proposed Weiss electro-magnet of 100 tons.

C, yoke, 60 tons; *N*, movable cores, 17.01 tons; *P*, polar outfit, three sets of conical polar pieces, one set plane, together about 5 tons.

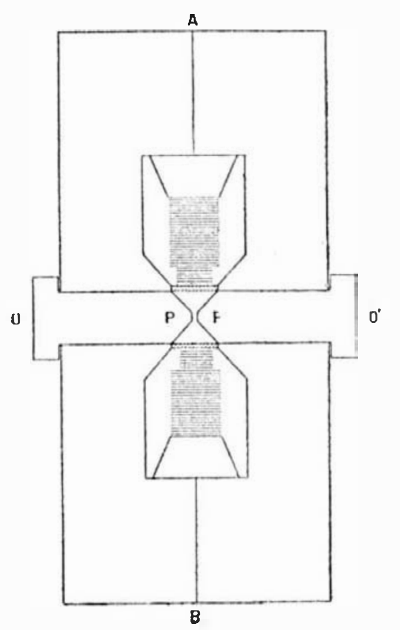


Fig. 16.—Diagram of Deslandres and Pérot electro-magnet.

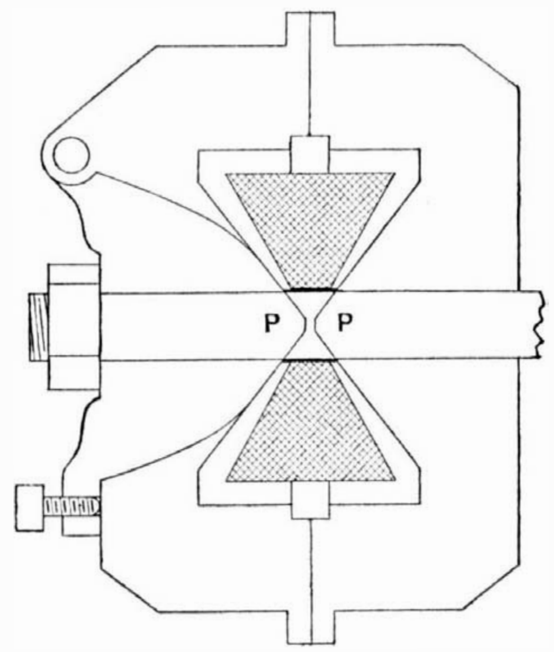


Fig. 17.—Another plan of Deslandres and Pérot apparatus.

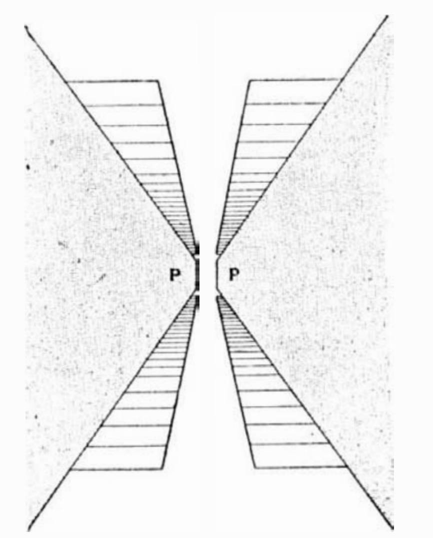


Fig. 18.—Diagram of polar coils of Weiss magnet.

The horizontal lines suggest various windings for greatest effect.

in weight. But on the other hand these fields can not be very extended and they require high electrical power so that the experiments are costly.

From the theoretical point of view the importance given to the ampere-turns is rational. One is led, however, to bring the windings more and more toward the poles, but as this is done and the coils are placed in such fashion that the direct action of the coils is greatest, they are at the same time in the position most awkward for experiments.

It is for this reason that Deslandres and Pérot have given to the interior bore of the coils a measure relatively high, ten times perhaps that usually employed. The fields that count in the experiments are only those which are within the bore, those that exist outside of this being worth nothing, though possibly a detriment. But to create these fields much energy is necessary; for 100,000 gauss with a gap of 7.5 millimeters, about 1,629 kilowatts being needed.

It has been already seen that with 1,420 kilowatts one may hope to obtain 100,000 gauss in a coreless coil of 20 millimeters diameter and that one can obtain this strength of field by cooling with water under pressure. The two types will give approximately equal fields with comparable costs. But it is true on the one hand that the great interior hollow is too large for real use, while in the smaller one there is still room for some kinds of experiments, the Zeeman phenomenon, for example.

Despite the great energy required in the electro-magnet of D. & P. it merits attention. The employment of the ribbon conductors and the way in which the cooling is effected should be especially noted. The square tubes are very practical, they make unnecessary the water-tight branch boxes, they permit of experiments with portions of coils and assure the excitation of the coil in a number of independent ways. But the employment of ribbons with the water circulation parallel to the axis, normal to the current lines and in very short courses, is truly original.

Prof. Cotton goes on to discuss some newer forms of the Weiss instrument. The fields just considered may reach 100,000 gauss, while those of the great Weiss apparatus give with little power very extended fields but with not more than 70,000 gauss. But the apparatus can be modified and so adapted as to give at will intense fields or extended ones.

Between the polar cones of this instrument there is considerable space. It is possible to adjust the polar coils, and the electro-magnet becomes one of two distinct windings, one about the cores and the other about the poles. With such an arrangement one may utilize the power available so as to have an instrument of great flexibility, a desideratum.

The use of supplementary coils is not new, Weiss having adopted them some twenty years ago, and others in the interim. It is with such coils that Weiss has produced the measured fields of 55,000 gauss. But the smaller apparatus has not served research because the field has been so restricted, only 2 to 3 millimeters. This will no longer be the case, for the larger forms possess larger gaps in which the fields can be really utilized.

Fig. 18 represents one of the pairs of polar coils under consideration by Weiss and Picard. The turns near the equatorial plane have been suppressed for convenience in working, although they would have been valuable for the field. The coils are relatively light, about twenty kilogrammes each, and they are easy to install when the poles are separated, as they may be by the motor.

This apparatus has been constructed so that the field will be about 30,000 gauss with the expenditure of about 100 kilowatts. It has been sought in the planning to approach the conditions of maximum service by varying the current density as indicated in the figure.

This is effected by making several concentric portions each uniform with itself, and the proposed mean densities are 200 amperes for the central winding and 50 and 12 amperes respectively in the two outer windings. One can increase the excitation in the outer windings, and with this the power, it being estimated that such a construction will give nearly 40,000 gauss with not more than 300 kilowatts.

There is no single way of representing the fields obtained by this principle; there will be as many characteristic curves as there are methods of dividing the windings. For great constancy it is desirable to give the electro-magnet windings the preponderance, but to produce a field as high as possible in a given gap, the field is likely to be less constant and more excitation should be given to the polar coils. A figuring of different conditions has been made in which the apportionment of the energy ranges from 200 kilowatts in the electro-magnet coils to 50, while that supplied to the polar coils varies at the same time from 100 kilowatts to a maximum of 300 kilowatts. The total in either event will not surpass 350 kilowatts.

FIELDS OF THE GREAT WEISS ELECTRO-MAGNET WITH POLAR COILS.

Air Gap in Millimeters.	Field in Gauss with 50 Kilowatts.	Field in Gauss with 200 Kilowatts.
3.0 by 2.0	100,100	108,100
5.7 by 3.5	94,500	102,500
5.7 by 5.0	91,400	99,400
5.7 by 10.0	85,200	93,400

A further use of the little polar coils is suggested in separating them from the large electro-magnet. Together with the ferro-cobalt cones they may be mounted in an inexpensive yoke and make little magnets for experimental purposes.

When it comes to the consideration of costs Prof. Cotton points out that the great electro-magnet will be the most costly portion. from 76,000 francs to 128,000, according to the price of copper. The more expensive outfit corresponds with the smaller running expenses. It is necessary moreover to provide for accessories, trucks, distributing system, the substation to transform into direct the alternating current of the district and a battery of accumulators. The whole will come near to 200,000 francs.

There is further than this the fact that it will not be wise to establish powerful instruments unless the current is assured as well as the funds for the initial plant. Then the costs attending the use of 1,500 kilowatts will be large. The University of Paris at the time of writing possessed the more important conditions, there being already established within its precincts the Aerotechnical Institute, a great laboratory that owes its establishment to the liberality of M. Deutsch de la Meurthe. It will presently be connected with an alternating current source of great power and will have its current cheap. It would be possible to place the magnets here.

But the optimistic writer hopes for better still. There is need of research of all kinds in this division of science, and it is to be hoped that a great laboratory of magnetism and magneto-optics may grow up about the apparatus. While modest equipment will undoubtedly lead to important discoveries it is not to be concealed that money is necessary to modern research, and there is obvious advantage in centralization. If only a laboratory could be established comparable to what that of Onnes is in the study of extreme cold, laboratory workers from all parts of the world would come to study. The better fitted the laboratory, the more completely will it attain this end.

Measuring Snowfall

THE French meteorologist M. Mougin speaks of the various ways of taking account of snowfall upon mountains. One point is to measure the height of accumulated snow upon a given surface, and such a nivometer he makes of a 1 meter square board held at about 1 meter height from the ground. After measuring the height of the snow, the latter is slid off into a zinc tank so as to melt the snow and measure the amount of water it furnishes. Another type of nivometer consists of a cylindrical tube which is run through the snow down to the ground or a prepared surface, and a spade is run underneath, then the tube and its contents of snow are taken out. Such work in estimating the height and bulk of snow can be done in meteorological stations which are inhabited, but where the stations are in remote places and are only visited at intervals, it is the practice to set up a container for snow as it falls, in which it is continually melted, thus taking only the volume of the water during a stated period. Such a device is easily made in the shape of a rather large cylindrical tank into which the snow falls and the water remains in the tank. But it is of course an essential point that the water should not evaporate. Vaseline oil is put in the tank in the first place, and it will then float on the surface of the water so as to effectually prevent evaporation. Melting of the snow is hastened by using chloride of calcium. He calls "specific lightness" the number which expresses the height of the snow in millimeters corresponding to 1 millimeter height of the snow water given by the melting of the same. It is reciprocal of the density. Snow varies extremely in density, and the figure expressing the lightness can vary between 200 and 1.3.

Shoal Water Corals*

The Ecology of the Floridian and Bahaman

By Thomas Wayland Vaughan, U. S. Geological Survey

MANY of the most important principles of coral ecology were long ago recognized and clearly formulated by Darwin and Dana. More recently Klunzinger, Pourtales, Moseley, Alexander Agassiz, Verrill, Stanley, Gardiner, von Marenzeller, Duerden, Wood-Jones, and others have made important contributions.

The coral faunas which live in water less than 25 fathoms deep in coral-reef regions are separable into two sub-faunas according to their ability for withstanding violently agitated water. These are (1) the strong, firmly attached, usually massive forms which can withstand breakers and the pounding of the surf; and (2) the weakly attached and branching forms which can survive only in quiet water. The forms requiring quiet water are further subdivisible according to their capacity to resist the deleterious effects of silt. A species of massive growth habit often will also live in quiet water. In some instances the same species of branching coral may be represented in both quiet and rough water, but the colonies in the rough water have shorter and stouter branches, responding to the environment by strengthening their skeletal structures. Massive, large, head-like corals, such as *Orbicella annularis*, form the strong framework of the reef, while in the interspaces between the heads many colonies of species of smaller size grow and other organisms are present in greater or less abundance. *Acropora palmata*, a species of another growth habit, is an important reef builder in places. It forms ascending fronds which by the thickening of their basal portion become very strong. Two species which live in the quiet water on the flats behind the outer reefs or in the lagoons are *Maeandra areolata*, which because of its small base of attachment could not remain fixed on the reef, and *Porites furcata*, which because of its fragile branches would be smashed to bits by the rough water of the outer reefs. These two species can exist where the bottom is muddy, as both possess the means necessary for ridding themselves of considerable quantities of silt. *Eusmilia fastigiata* is a species which has a fragile skeleton and requires quiet water, but as it can not endure much silt, it is restricted to areas where the bottom is cleaner. *Porites clavaria* illustrates responsive adaptation to environment, as it lives both on the reef and on the inner flats. The branches of the colonies in the former habitat are short and stumpy or the colony may be almost massive in growth form, while in quiet water the branches may be decidedly elongated.

The depth to which the more massive forms extend is between 18 and 31 meters; 18 meters is usually about the maximum for vigorous growth, but some of the branching species extend to slightly greater depths. In general the lower depth of the shoal-water coral fauna of the West Indies is about 37 meters, approximating conditions in the Pacific. The precise cause of the limit in depth has not been determined. Each of several possible factors will be discussed.

All the corals with which I have experimented possess the capacity of removing a certain amount of sediment from their surfaces. This is affected by the non-nutrient particles becoming imbedded in mucus and by cilia removing the mucus and the particles from the surface of the tissue. The capacity for cleaning their surfaces varies according to the species, it being lowest among those corals which are most important on the outer reefs —it is low in *Orbicella annularia* and high in *Maeandra areolata*.

Some corals, as *Siderastrea radians*, can endure having their surfaces covered with silt for some time. This coral seems to secrete a layer of mucus which lifts the silt above the tissue surfaces and thereby protects them. The branching form of many corals prevents sediment settling on them faster than it can be removed. However, as any coral will be killed by actual burial beneath sediment, corals cannot live where sedimentation is rapid; and as sediment accumulates in areas deeper than the base of strong wave action or where currents are weak, it is a factor in limiting the depth to which the littoral fauna can extend.

The mechanism of corals for catching food are as follows: (1) The ectodermal surface is beset with nematocysts, which occur on the tentacles, the oral disk, the column wall, including its downward extension called the edge-zone, and also on the margin of the mesenterial filaments. (2) The entire ectodermal surface is ciliate, the cilia in response to certain stimuli beating toward the oral apertures; in response to others, beating toward the periphery. (3) The outer surface secretes mucus in which particles may be embedded, the mucus moving under the influence of the beat of the cilia toward the oral apertures or toward the periphery, according to the nature of the response to the stimulation. (4) The tentacles are active and effective in capturing food. (5) The mesenterial filaments, which in many species of corals can be extruded through the column walls, in some instances capture food.

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Many different kinds of food were offered corals, but they took only animal food; they are entirely carnivorous. The following experiment was tried many times: A piece of diatom mat was placed on one side of the oral disk and a piece of crab meat on the other. Invariably the crab meat was seized and swallowed; while the diatoms induced no reaction except ultimately to be removed from the surface. No kind of purely vegetable food was taken by any one of the numerous species investigated. However, pieces of plants coated with small animals or soaked in meat juice will be swallowed, and later the vegetal matter ejected.

As the food of corals is purely animal plankton, a decrease in the amount of this food-supply with increasing depth would limit the downward distribution of the shoal water forms, but as I do not know of any quantitative estimates of the amount of animal plankton above and below 20 fathoms in coral reef areas, there is no basis for a positive opinion.

The relation of corals to light was studied. Specimens of 17 species were put into a darkened, light-proof live-car. One of the number was dead at the end of 14 days; three others were dead at the end of 28 days; while eleven species survived at the end of 43 days. However, all had become pale, some even colorless, or otherwise showed abnormalities. A natural experiment, which appears conclusive, is afforded by Fort Jefferson wharf. Here corals thrive on all the outer piers where the light is strong, but there are none on the central piers where there is perpetual shade. It, therefore, seems to me that strong light is essential for the vigorous growth of shoal water corals.

Another factor is temperature. Dr. Mayer conducted a series of experiments to ascertain the higher and lower limits of temperature which the common corals around the Tortugas can endure. These indicate that a lowering of the temperature to 13.9 deg. Cent. would exterminate the principal Florida reef corals, while the most important inner flat corals would survive. He obtained similar results on the corals around Murray Island, Australia.

Dr. H. F. Moore of the U. S. Bureau of Fisheries has communicated to me temperature records made at lighthouses along the Florida reef. These show that vigorous reefs will endure a temperature as low as 18.15 deg. Cent., the minimum at Carysfort light between 1879 and 1899; but at Fowey Rock, where the minimum drops to 15.6 deg. Cent., although there are some corals, there is no thriving reef. The species found at the north end of the reef line are those which Dr. Mayer's experiments showed capable of withstanding the lowest temperature. The temperature records for the reef line indicate 18.15 deg. Cent. as the minimum temperature which a reef will survive; this is 1.85 deg. Cent. lower than the figures given by Dana. It is not probable that a reef could withstand a continuous temperature so low as this. Wherever the depth of water is great enough to lower the bottom temperature below 18.15 deg. Cent., more probably about 21 deg. Cent., reef corals will not live. This temperature appears to be attained around the Hawaiian Islands within a depth of 183 meters. According to Agassiz's "Three Cruises of the Blake" the bottom temperature in the Gulf of Mexico and Caribbean Sea is usually too low for the growth of reef corals at a depth of 183 meters, and in places it is too low at a depth of 87 meters. Although the possibility of control of the lower bathymetric limit of reef-building corals by decrease in temperature with increasing depth has not been adequately investigated, it appears safe to say that reef corals are usually, if not always, confined by temperature to water less than 180 meters deep.

The four possible factors which tend to limit the downward extent of reef forming corals are as follows: (1) effect of sediment; (2) decrease in supply of small animal plankton; (3) decrease in intensity of light; and (4) lowering of the temperature.

The relations of corals to salinity will now be considered. The average salinity of the Tortugas water according to Dole is 36.01 per cent. Seventeen species of the Tortugas corals were kept in a large tank of water with a salinity of 18.28 per cent for 24 hours. All were damaged or killed except *Maeandra areolata*, *Siderastrea radians*, and *Porites astreoides*, but no specimen of 16 species showed any evidence of harm after remaining 48 hours in water of a salinity of 27.87 per cent. Apparently corals would not be hurt if the salinity of the ocean were reduced to about 80 per cent of its present salinity. Although I did not experiment with concentrated sea-water, the studies made by Goldforb and others on the effect of concentrated and diluted sea-water on regeneration in hydroids and in the *Cassiopea* are here pertinent. The combined results of the experiments are in accord with the deductions made by oceanographers and geologists from other data, viz., the ocean is becoming more salt, and it appears that marine organisms are now living in an environment which is considerably below the optimum condition for their existence.

In order to ascertain the amount of atmospheric exposure corals would endure, experiments were made on 16 species, any of which will endure exposure on a glass plate in the shade for half an hour without apparent damage; nearly all will stand an hour without harm, while some will stand 4 hours' exposure under the conditions stated. *Favia fragum*, *Porites clavaria*, and *Porites astreoides* have the greatest capacity for withstanding atmospheric exposure, while that of *Maeandra areolata* and *Siderastrea radians* is almost as great. A number of species withstood exposure on a glass plate in the sun for 1½ hours, the specimens being badly damaged, but not entirely killed. Although not precisely true, in general the ability to withstand atmospheric exposure is a function of the porosity of the skeleton, the species with the more porous, surviving longer than those with the denser skeletons.

The conditions necessary for vigorous coral reef development may be summarized as follows: (1) Depth of water, maximum, about 45 meters; (2) bottom firm or rocky, without silty deposits; (3) water circulating, at times strongly agitated; (4) an abundant supply of small animal plankton; (5) strong light; (6) temperature, annual minimum not below 18 deg. Cent.; (7) salinity between about 27 per cent and about 38 per cent.

In the experiments on rearing corals, the planulæ were removed with a pipette from the vessel containing the parent colony to a jar on the bottom of which was a terra-cotta disk. Although the planulæ will live a long time, even settle in stale water, kept at the proper salinity, it is better to change the water at least once a day. To change the water, siphons were used, a fine-mesh bolting cloth bag having been tied on the end within the jar, so as to prevent the escape of the planulæ; while clean water was added through siphons from jars placed at a higher level.

Because of its bearing on the possibility of the distribution of coral species by oceanic currents, it is highly important to know the duration of the free-swimming larval stage. Observations were made on four species. The range was from 2 to 23 days. Should an ocean current have a velocity of 3 knots per hour in 23 days planulæ might be carried 1,656 knots; at 2 knots per hour 1,104 knots; at 1 knot per hour 552 knots. It is known that every species of shoal water coral in the Bermudas is found in Florida and the West Indies; while not only is the Hawaiian fauna Indo-Pacific in its facies, but several of the species (at least 4) also occur on the east coast of Africa or in the Red Sea. I seriously doubt any part of the Hawaiian fauna being peculiar to those islands. The clue to the cause of the wide distribution of living coral species is given by the possibly long duration of the free-swimming larval stage.

The growth rate of corals was determined by planting planulæ which attached themselves in the laboratory, by measuring colonies, from planulæ which settled on collectors in a known season, by measuring colonies cemented to disks and fixed on the heads of stakes driven into the sea-bottom, and by measuring colonies naturally attached. The plantings around the Tortugas were made on the reef off Loggerhead Key and on the outside of Fort Jefferson moat wall, while records were made on colonies growing naturally attached at the two stations mentioned, on the piers of Fort Jefferson wharf, and in Fort Jefferson moat. The observations in the Bahamas were made on artificially planted and naturally attached colonies at the east end of South Bight, Andros Island. The Florida corals were measured annually; those in the Bahamas were measured in 1912 and again in 1914. The average growth rate for each species at each station has been computed. The size of the colonies of all species of corals seems limited, but some attain large dimensions, 2 to 3 meters or even more in diameter, and nearly as much in height, while other species are adult when a diameter of 35 to 50 millimeters has been reached. *Favia fragum* and *Maeandra areolata* are instances of species which grow relatively rapidly for the first 2 to 4 years,

after which they grow more slowly. *Orbicella annularis* and *Maeandra stigosa* are not so limited in size. Branching corals grow more rapidly than massive species; while of the former, the growth rate of species with perforate, loose-textured skeletons is more rapid than that of species with dense skeletons. In general the more massive and the denser the corallum, the slower the growth; while the more ramose and the more porous the skeleton, the more rapid the growth.

There is no average growth rate for corals generally speaking, as growth rate varies from species to species, and varies for the same species according to local environmental conditions. Here it may be said a colony of species of reef coral in a lagoon, if protected from sediment, may grow more rapidly than a colony of the same species does on the reef. The limitation of reef corals so largely to the outer edges of platforms is determined primarily by purity of water, i. e., freedom from silt, and by the more uniform temperature.

In order to estimate the rate at which a reef will grow, the upward growth rate of the true reef-forming species must be taken. The upward growth rate of *Orbicella annularis*, the principal builder of the Pleistocene and living reefs in Florida and the West Indies, is from 5 to 7 millimeters per year, according to station. At 6 millimeters per year, it would form a reef 150 feet thick in 7,620 years; at 7 millimeters per year it would build the same thickness of rock in 6,531 years. *Acropora palmata*, which grows more rapidly, might build a similar thickness in 1,800 years. The growth of corals in the Pacific appears to be more rapid and according to Stanley Gardiner they might build a reef 150 feet thick in 1,000 years. The investigation of the growth rate of corals shows that any known living coral-reef might have formed since the disappearance of the last continental ice sheets.

Notes on Plant Chemistry*

Some of Little-known Characteristic of Common Flora

By P. Q. Keegan, L.L.D.

Hair Moss (*Polytrichum commune*).—This plant assembles in dense tufts and cushions of deep greenery on heaths, moist woods, and turbaries. Its chemistry is rather tame, and apparently not specially indicative of any specific physiological activity; one reason for which may be that the constituents for the most part are not readily extracted by the ordinary menstrua, or only in such quantity as renders their mode of origin or their functions rather dubious. However, I will now relate the facts of the analysis as follows: In June the dried moss yielded to boiling benzine 1.1 per cent of an unsaponifiable waxy matter which was tinged by a trace of carotin, and there was no phytosterol. The alcoholic extract contained some more yellow wax and a little chlorophyll, and its aqueous solution was acid and faintly bitter, had traces of a saponin apparently, and responded very clearly to the tests for saccharose. Further treatment of the residue of the plant indicated the presence of nitrate, much pectosic mucilage, and pentosan, a little starch and cellulose hydrate (amyloid, perhaps), and a red-brown resinous matter extractable by dilute soda and soluble in sulphuric acid with a brown color. There was no dextrine, alkaloid, or oxalate. The ash of the plant in October was about 2.4 per cent, and contained 16.4 per cent soluble salts, 45.8 silica and sand, 7.3 CaO, 3.4 MgO, 12.1 oxide of iron, 4.3 P_2O_5, 3.7 SO_3, with some manganese and traces of chlorine and carbonate. In June the ash contains 41.9 per cent soluble salts and only 16.3 silica. At first sight the above analysis seems rather meagre, but if we carefully observe the habit of the plant, and are aware that the protoplasm of mosses is extremely sensitive to the influence of the contents of the currents of water which traverse their tissues, we must conclude that they are capable of a pretty active power of assimilation. The array of vertical cells on the upper surface of the leaves, when exposed to the air in a moist atmosphere, produce starch, oil, etc., very rapidly and efficiently. Moreover, the humus of the heaths and tubaries where it grows contains colloidal combinations of the diverse constituents of the carbonaceous destruction of plants, and these, being taken up by the rootlets or root hairs and digested there, are absorbed or assimilated by the protoplasm in the form of condensed carbohydrates. As regards the process of deassimilation, it proceeds no further than the formation of a resin which is yellowish, has an acid function, and yields no special reactions. This resin plugs up the intercellular spaces and the stomatic air-cavities in the lower portion of the stem, and thus greatly slackens the physiological activity and modifies the protoplasmic content of the cells situated there, thus clearly showing that this part of the organism is of no further service after the fruiting is accomplished. Although Czapek by long boiling with water or dilute soda under pressure apparently extracted a phenolic and a tannic body from the cell-wall of various mosses, I am not convinced that these bodies exist there as original constituents. After careful examination I am inclined to conclude that the yellow color given to the cell-wall of mosses by soda and the reactions of same given by $FeCl_3$ and by Millon's reagent are due to some humin matter sucked up from the soil into the tissues, similarly as certain fungi, according to Nuemann, can absorb tannin (0.04 per cent) into their tissues, where it is chemically decomposed. Mosses are very tenacious of life, the term of their existence is in most cases unlimited, every part of them may give rise to protonema; i. e., a rudimentary shoot and thallus, and those species which inhabit moist places emit a great quantity of CO_2. All these properties seem to be connected with the essentially reproductive character of their cells; i. e., they have a clearly defined nucleus and abundant white translucent alkaline protoplasm, the vacuoles of which have no supply of nutriment, organic or inorganic. The doctrine of evolution has been sharply held up by mosses, no passable bridge having been found between them and the algæ on one side and the ferns on the other. Mosses may perhaps be a sort of "reproductive" offset, from say, grasses; but in that case the plant evolution theory would be worse confounded than before.

Early Purple Orchis (*O. mascula*).—This plant is found in meadows, and in certain parts of woods and pastures where there is no rich supply of food salts. It is a succulent plant of slow growth and very difficult to cultivate artificially, its germination necessarily requiring the concurrence of fungi, which frequently depends on chance. The mycorhiza exist always inside the cells of the roots (not of the tubers) as pellets of compact filaments (hyphæ), which are sometimes ultimately completely digested by the plant. Hence, it would seem, as Gallaud opines, that the supposed symbiotic nature of these mycorhiza is more like that of a parasite, but their infestation serves to react in a physico-chemical manner upon all the tissues of the plant. On June 20th, 1915, the dried over-ground parts of the plant yielded to boiling benzine 1.7 per cent of wax, with a very little carotin and some fat oil; the alcoholic extract had a bitter taste, and contained a moderate quantity of flavone giving the reactions of quercitrin, also a large quantity of free glucose, and some resin and bitter principle which gave no green coloration when warmed with nitric acid. There was no nitrate, tannin, alkaloid, or starch, but much pectosic mucilage and a little pentosan; also a considerable amount of oxalate of calcium reprecipitating in fine crystals after extraction; the crude fiber amounted to 40 per cent of the dried material. The ash of above was 6.5 per cent, and contained 47.3 per cent soluble salts, 5.2 silica, 20.5 CaO, 3.8 MgO, 7.8 P_2O_5, 3.8 SO_3, and 7.8 Cl; there was much soluble carbonate, and about 3 per cent oxides of iron and manganese. The tubers when young contain starch, sucrose, volatile oils, and mannan, but no inulin, as reserve substances which are mostly used up at flowering time, when a new tuber is immediately produced and rapidly forms similar reserves as before. The floral organs of orchids have commanded much attention for many years; in the plant under review the corolla is of a rich purple color, though there is no tannin in any of the organs; the conditions, viz., the lanceolate leaves rarely rising far from the ground, and the long bare stem are exactly those which specially favor the development of anthocyanic pigment in the corolla. Blue flowers are said to occur in three genera of Orchidaceæ, but the presence of quercitrin or quercetin in the order induces me to conclude that these are not true blues. I have noticed that this orchid does not grow on specially damp peaty places, so that the fact as shown by the above analysis that it contains no starch and little pentosan is readily explained. The most remarkable fact is the presence of free aldehydic sugar, and a portion of a gathering got in June being left in a closed drawer for five months was found to still retain a large amount of the same reducing substance. "Succulent plants," say André, "possess a kind of very special vegetation which is revealed by their tenure of organic acids and by remarkable peculiarities as to what concerns the variations in the soluble amides and the ternary matters." The protoplasm of succulent plants has special properties, and the high percentage of water favors and prolongs the phenomena of the dissolving power of the diastases on the starch, etc. Such would seem to be the prevalent view of cases like this one; but the meadow land rich in humus formed from the *debris* of certain plants seems to accumulate carbon in a special manner, which, being absorbed by the roots and tubers of the orchid, are digested there, and when the transpiration is strong, as in the fleshy leaves of some tropical orchids, copious starch is formed thereby; whereas when the transpiration is feeble, soluble carbohydrates are alone produced. According to Van Tieghem the tuber of the orchid under review is composed of a number of separate roots which have a common growth, and all constitute together a single tuber, and hence it is really a tuberous root; if it were not so it would be difficult to explain the presence therein of some of its chemical constituents. It is admitted that carbonaceous matter may be absorbed by the roots of plants, but the amount of it thus taken up is too small to be worth considering. I do not agree with this opinion. I am firmly convinced that it is impossible to explain the very large amount of starch and mucilages contained in the stem and leaves of various marsh and water plants which I have analyzed, if it be contended that these carbohydrates are originally produced only and solely by the action of the leaves or other organs evolving chlorophyll. According to Griffon, the non-green species of Orchis, such as *Neottia*, which is all pale reddish-brown, are capable owing to their mycorhiza of extracting their carbon from humus matters. On the other hand, André in 1912 declared that "the carbon nutrition of the plant at the expense of the humic matter of the soil has not yet been proved." Nevertheless, I think that if a certain number of marsh plants were examined, the standard of proof as respects this question will be raised very high.

Marsh Marigold (*Caltha palustris*).—This plant flourishes most effectly on valley bottoms of black muddy soil on stream-edges, or often partly submerged. It belongs to the hellebore tribe of the much discussed order Ranunculaceæ, which, according to some systematists, ranks among the highest Angiosperms, while others regard them as merely Monocotyledons. On May 15th, 1915, the dried leaf blades extracted boiling benzine yielded 1.6 per cent of much carotin, with some wax and a little fat-oil. The alcoholic extract contained much flavone, which was a mixture of iso-rhamnetin with a little quercetin. There was also an acrid resinous glucoside (helleborin) like a saponin, and about 2 per cent caffetannin. Further treatment showed the presence of sucrose, a large quantity of mucilage (secreted by glands in the teeth, the sheaths and the nerve-grooves of the leaf), also pentosans, some nitrate, but no reserve starch or oxalate of calcium. Warm dilute HCl extracted a small quantity of an alkaloid which seems to be veratrine, as it gave a bluish reaction with H_2SO_4 and sugar. There was 9.7 per cent of ash, which contained 43.5 per cent soluble salts, 6.5 silica, 19.1 CaO, 4 MgO, 5.5 P_2O_5, 5.3 SO_3, and 8.7 Cl, with only a little iron and manganese and no soluble carbonate. The special feature of this analysis is the presence of caffetannin along with quercetin, which latter, however, may not be actually present as such in the plant, but only split off during the analysis from the iso-rhamnetin; the presence of copious mucilage is incidental to the root action already specified. The floral organs yielded 2.6 per cent of carotin and wax; they had also iso-rhamnetin, but no quercetin or tannin; also very much mucilage, but no starch; the ash yielded 55.2 per cent soluble salts, 5.3 silica, 9.2 CaO, 6.2 MgO, 10.9 P_2O_5, 7.1 SO_3, and 5.5 Cl; there was much soluble carbonate and a little manganese. It must be noted that the floral envelopes are formed of sepals and not of petals, and are, therefore, of a vigorous anatomical structure, have stomata, and their protoplasm is capable of differentiation with production of chromoplasts which by a process of assimilation evolve starch, fat-oil, protein crystals, chlorophyll, and the carotin, which aided by the shimmer of the oil imparts a brilliant golden, almost fiery, aspect to these organs. The root is of the hydrophile type and has long, cylindrical, unbranched side-roots; it contains starch, but was not further examined. The black mud in which it grovels is supposed to be brought about by the action of molds (not bacteria), which only grew in a neutral medium and

* The *Chemical News*.

are said to take part in the mineralization of organic nitrogen; they reabsorb the ammonia and produce new amido-nitrogenous substances. The analysis of the Marsh Marigold is specially interesting, inasmuch as it enables us to propound three important results of a general nature, viz.: 1. The production of mucilage is in no way related to the production of oxalate of calcium. 2. The absorption of humic matter from the soil serves apparently as a basis for the formation of mucilages and hemicelluloses, but not of starch and certain sugars. 3. It would seem that plants which bear flowers tinctured by carotin require, even when the top soil is peaty, a substratum of sand or gravel where the relation of nitrogen to carbon is rather high, i. e., where abundant soil nitrogen is readily available, and may be easily absorbed by the roots. Most yellow-flowered plants seem to grow on dry calcareous or non-peaty soils, as in the famous "Sunflower State" of Kansas, U. S. A. On the whole I am inclined to conclude that Ranunculaceæ, although structurally comparable to Monocotyledons, are chemically superior thereto.

Some Woodland Phenomena.—Of all our native trees the Alder is perhaps the most difficult to analyze satisfactorily. One special reaction may be noticed. The bark of a twig cut in March was boiled in water, and on adding to the filtered cold solution one drop of hypochlorite of sodium solution a deep indigo-blue coloration was immediately produced, which vanished almost at once; this was repeated two or three times with a similar result, but finally no blue was observed. So far as my experience of plant extracts has gone this reaction is absolutely unique. It was not given by the tannin alone, or by the emodin alone, which occur in this bark. It would appear according to my examination that alder tannin does not contain a phloroglucol nucleus, and also that its phlobaphene is easily alterable, so that the emodin is probably formed by its oxidation with loss of water and destruction of the phloroglucol nucleus.

By kind permission I was enabled to examine the leaves of a beautiful British grown specimen of the mammoth tree of California (*Sequoia gigantea.*) Without going into detail I may mention that the waxy and resinous constituents of these leaves gave no special reactions; there was little carotin, but much phytosterol. There was a little tannoid, probably fisetin. The tannin was powerfully reductive, and gave the usual reactions of a catechol very decisively, and although it precipitated tartar emetic at once, gave a bluish solution with Fe powder, and faintly greenish precipitates with baryta water and with Millon's reagent, it yielded no gallic acid when boiled with dilute acids. It yielded a specially beautiful phlobaphene, indicating the absence of "humin" in the extracts, or of any decomposition of tannin in the leaves, and this, in fact, seems to be characteristic of all the Coniferæ that I have examined, which means that these tannins are very stable, and are free from carbohydrate contamination owing to a particular construction of the vascular system of the trees. The leaves also contained much gum and much sucrose, or a glucoside yielding it. After steeping in cold benzine or cold alcohol, drying, and then boiling in water, a large quantity of starch was extracted. There was also much pectosic mucilage, and the reactions of pentosans were very pronounced. There was no alkaloid or oxalate of calcium. According to Heyl the tannin of this *Sequoia* cone yields phlobaphene, and some gallic acid and sugar when boiled with dilute sulphuric acid; this is probably correct, as the tannins of fruits seem generally more readily oxidizable than those of leaves, or sometimes even of barks.

Aeroplane Stability

Some phases of fore-and-aft or longitudinal equilibrium in flying are discussed by Dr. Orville Wright in a recent publication of the Smithsonian Institution, entitled "Stability of Aeroplanes." Mr. Wright says that a flying machine is balanced in three directions—about an imaginary axis fore and aft in its line of motion, referred to as lateral equilibrium; about another axis extending in a lateral direction from tip to tip of the wings, known as fore-and-aft or longitudinal equilibrium; and about a vertical axis, which is generally referred to as steering, although its most important function is that of lateral equilibrium. Although a beginner finds most difficulty in mastering the lateral control, it is his lack of knowledge of certain features of the fore-and-aft equilibrium which leads to most of the serious accidents.

In an ideal flying machine the center of gravity would lie in the line of the center of resistance to forward movement and also in the line of thrust, but in practice this is not always feasible, since the machine must be built to land safely as well as to fly. In flying, a low center of gravity, that is, one below the center of support, causes an oscillating movement about the lateral axis like that of a pendulum, which tends to form a disturbing turning movement. On the other hand, a high center of gravity tends to cause the machine to roll over in landing, and consequently a compromise is adopted.

The two principal methods used in preserving fore-and-aft equilibrium have been the shifting of weight so as to keep the center of gravity in line with the changing center of lift, and the utilization of auxiliary surfaces, known as elevators, to keep the center of pressure in line with a fixed center of gravity. The first method has been found impracticable on account of the impossibility of shifting large weights quickly enough, but the second is used in most of the modern flying machines.

Flying machines of the latter type should have their auxiliary surfaces located in the front or rear, and as far as possible from the main bearing planes, because the greater the distance the greater is the leverage, and consequently the smaller the amount of surface required. No part of either the main surface or auxiliary surface should be exposed on their upper sides in a way to create a downward pressure for maintaining equilibrium, since such a pressure requires twice the propeller thrust to overcome it that an equal carried weight would require.

The downward pressure of air is used to some extent, however, on account of its adaptability in producing more or less inherent stable aeroplanes. Mr. Wright describes an inherently stable aeroplane as one in which equilibrium is maintained by an arrangement of surfaces so placed that when a current of air strikes one part of the machine, creating a pressure that would tend to disturb the equilibrium, the same current striking another part creates a balancing pressure in the opposite direction. This compensating or correcting pressure is secured without the mechanical movement of any part of the machine. While this system will control a machine to some extent, it depends so much on variation in course and speed as to render it inadequate to meet the demands of a practical flying machine.

In order to secure greater dynamic efficiency and greater maneuvering ability, auxiliary surfaces mechanically operable are used in present flying machines instead of the practically fixed surfaces of the inherently stable type, but they depend to a greater extent upon the skill of the operator in keeping equilibrium. If the operator were able to "feel" exactly the angle at which his aeroplane meets the air, at least 90 per cent of all aeroplane accidents would be eliminated. Instruments for this purpose have been produced, but they are not in general use. The average flier does not realize how dangerous it is to be ignorant of this angle, nor does he know when he is "stalling." By "stalling," Mr. Wright means coming to rest in the air, or nearly so.

The danger from "stalling" comes when the operator attempts to check the machine's downward plunge by turning the main bearing surfaces to still greater angles of incidence, instead of pointing the machine downward, at a smaller angle of incidence, so that the speed can be recovered more quickly. Most of the serious accidents in flying occur, after long glides from considerable heights with the power reduced, when an attempt is made to bring the machine to a more level course several hundred feet in the air. The machine quickly loses its speed and becomes "stalled." Those who have seen the novice make a "pancake" landing have seen the beginning of a case of "stalling" which might have been fatal had it taken place at a height of 100 or 200 feet in the air.

The greatest danger of flying comes from misjudging the angle of incidence. If a uniform angle were maintained there would be no difficulty in securing fore-and-aft equilibrium. Experiments made during the past year or two have brought about a considerable advance in the development of automatic stability. A device described by Mr. Wright comprises a small horizontal wind vane so mounted on the machine as to ride edgewise to the wind when the machine is flying at the desired angle of incidence. In case the machine varies from the desired angle, the air will strike the vane on either its upper or lower side. The slightest movement of the vane in either direction brings into action a powerful mechanism for operating the controlling surfaces. If the wind strikes the vane on the under side, the elevator is turned to cause the machine to point downward in front until the normal angle is restored, and if the air strikes the vane from above, an opposite action upon the elevator is produced. The author maintains that a machine controlled by regulating its angle with reference to the impinging air is not liable to the dangers of "stalling."

Another method for maintaining fore-and-aft equilibrium utilizes the force of gravity acting on a pendulum or tube of mercury, and a second employs the gyroscopic force of a rapidly revolving wheel. In both of these systems, however, the angle of the machine is regulated with reference to the horizontal, or some other determined plane, instead of the angle of the impinging air. Other faults render the pendulum and mercury tube useless in regulating fore-and-aft equilibrium, although the pendulum is found to be useful in regulating the lateral stability.

Mr. Wright believes that the day is near at hand when the flier will be almost entirely relieved of the work of maintaining the equilibrium of his machine, and his attention will be required only to keep it on its proper course and to bring it safely in contact with the ground when landing.

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