THE WORKING AND MAINTENANCE OF STEAM BOILERS.

IN these days of high-priced coal, the memorandum which has recently been issued by Mr. C. E. Stromeyer, chief engineer of the Manchester Steam Users' Association, will be read with much interest by engineers and boiler owners. The coal bill for a Lancashire boiler amounts to from 300*l.* to 600*l.* per annum, and careless stoking may easily increase this cost in a very large proportion. Lack of proper attention to minor defects, which should be remedied as soon as detected, may also greatly increase the coal bill and shorten the life of the boiler. The memorandum covers a very wide field, such as economiser defects, external and internal corrosion, leakage, etc. Of special interest are Mr. Stromeyer's remarks regarding mechanical stokers.

Experience indicates that mechanical stokers, which naturally aim at improved efficiency and therefore high furnace temperatures, require not only that they should be carefully looked after and kept in good repair, but also that the boiler should receive far more care and attention than are necessary with hand-firing. Scale, and to a certain extent grease, may be tolerated in hand-fired boilers, but every effort should be made to remove these injurious substances if increased economy is aimed at by the adoption of mechanical stokers. Mr. Stromeyer gives some illustrations of the increased liability to damage due to increase in the temperature of the furnace. The boilers of a large steamer had been giving no trouble until an improved fire-grate was fitted. A saving of about 10 per cent. in the coal bill resulted, but during the next voyage all the eighteen furnaces gradually bulged, in spite of a reduction of speed and power. The bulging could have been stopped if the improvement due to the new grate had been nullified either by keeping the furnace doors open and admitting an excess of cold air, or by closing all airholes in the doors, restricting the air admission but spoiling the efficiency.

Mechanical stokers designed to burn anthracite will almost certainly fail if fed with coking coal, and *vice versa.* It is not possible to design a mechanical stoker which shall be satisfactory with all classes of coal.

From an economical point of view it is more important to keep the boiler heating surfaces free from soot and tarry matter than to remove the scale from the interior surfaces; the wear and tear question, however, demands that the inside of a boiler should be kept clean. Scale and grease hinder the heat which enters the plate from passing into the water. The radiating power of incandescent fuels, or flames, increases as the fourth power of the temperature, hence boilers which have worked satisfactorily, but inefficiently, with a comparatively low furnace temperature, even though the plates may be covered with scale or grease, are likely to give trouble if the furnace temperature, and with it the efficiency, are increased. It is not strictly true to say that scale and grease reduce the efficiency of a boiler; they merely make it unprofitable to adopt an efficient system of combustion.

Slow bulging of the furnaces may be caused by the deposition of scales of crystals from any boiler water containing more than 4 per cent. of soluble salts. It is more than probable that plates which on one side are exposed to an intense heat, are on the other side covered chiefly with bubbles and sprays of burst bubbles, which leave their dissolved salt on the boiler plate while the water is evaporated. If the intense heat and rapid evaporation can be maintained locally, and this seems to be the case if mechanical stokers are worked very hard, crusts of salt will form here and there on the heating surface. Sometimes they will be washed away with a slight change of evaporation or circulation, but sometimes they will remain attached to the plates for a sufficiently long period to cause overheating. Drops of water which fall on hot plates are in a spheroidal condition, do not wet the plate, and consequently will not dissolve any salt scale which has formed there. As soon as a little bulging has been effected, the salt crusts will doubtless break off, but as bulges are exposed to the flames more than other parts, salt crusts are likely to reform in them, and gradually the bulge grows larger and larger until it is detected. As soon as the fire is drawn the salt crusts are dissolved away, and the bulges are said to be due to mysterious causes. This danger is naturally greatest with boilers having a bad circulation.

BEHAVIOUR OF PLANTS IN RESPONSE TO THE LIGHT.[1]

IN the whole realm of biological science there is perhaps no phenomenon of greater fundamental importance than that exhibited by green plants in the transformation of carbon dioxide and water into starch and sugar. That this can only take place through the action of light upon chlorophyll is commonplace knowledge, but exactly how it is effected we do not know. Of the light that falls upon a green leaf a part is reflected from its surface, a part is transmitted, and another part is absorbed. That which is reflected and transmitted gives to the leaf its green colour; that which is absorbed, consisting of certain red, blue, and violet rays, is the source of the energy by means of which the leaf is enabled to carry on its work.

The extraordinary molecular complexity of chlorophyll has recently been made clear to us by the researches of Willstätter and his pupils; Usher and Priestley and others have shown us something of what takes place in chlorophyll when light acts upon it; and we are now beginning to realise more fully what a very complex photo-sensitive system the chlorophyll must be, and how much has yet to be accomplished before we can picture to our minds with any degree of certainty the changes that take place when light is absorbed by it. But the evidence afforded by the action of light upon other organic compounds, especially those which, like chlorophyll, are fluorescent, and the conclusion according to modern physics teaching that we may regard it as practically certain that the first stage in any photo-chemical reaction consists in the separation, either partial or complete, of negative electrons under the influence of light, leads us to conjecture that, when absorbed by chlorophyll, the energy of the light-waves becomes transformed into the energy of electrified particles, and that this initiates a whole train of chemical reactions resulting in the building up of the complex organic molecules which are the ultimate products of the plant's activity.

The absorption of light by the leaf is therefore of great physiological importance, and we have only to look at any of the plants around us to see how successfully they contrive to arrange their leaves to obtain the maximum advantage from the light that falls upon them. A plant organ responds to the directive influence of light by a curvature which places it either in a direct line with the rays of light as in grass seedlings, or at right angles to the light as in ordinary foliage leaves.

[1] Evening discourse delivered before the British Association at Manchester on September 9, by Dr. Harold Wager, F.R.S.

Formerly it was thought that the light acts directly on the part that bends, but the researches of C. and F. Darwin more than thirty years ago proved that in young seedlings this is certainly not the case. They showed quite conclusively by means of a large number of carefully contrived experiments that the heliotropic curvature in the lower part of a seedling is determined by the illumination of the upper part. Consequently no curvature can take place until a stimulus has been transmitted from the upper part, which behaves as a light-perceiving organ, to the lower part in which the motor response takes place.

Foliage leaves are not usually so sensitive to light as the plumules of young seedlings, and do not in many respects so readily admit of experimental investigations. We know that the leaf-stalk bends towards and tends to place itself parallel to the rays of light, and that the leaf-blade places itself at right angles to the rays of light. We know that when the leaf reaches the position of maximum advantage the movement towards the light ceases, and it then remains fixed, except for slight circumnutating movements, until either the direction of the light changes or its intensity is decreased. But we do not yet know —and the problem is not an easy one to solve—by what means the leaf is enabled to adjust its position to the direction of the rays of light, nor just how it perceives that it is or is not in the most advantageous position.

FIG. 1.—*Eranthis hiemalis.* Leaf stalks curving towards light coming in the direction indicated by the arrow.

Dutrochet suggested, without any experimental evidence to support it, that the lamina of the leaf exerts an influence on the movement of the leaf-stalk. Hanstein also considered that the lamina was the light-sensitive part of the plant, and even went so far as to compare it with the retina of the eye. C. and F. Darwin were the first to attempt to determine the point experimentally.

Pieces of blackened paper were gummed to the edges and over the blades of some leaves on young plants of *Tropaeolum majus* and *Ranunculus ficaria*; these were then placed in a box before a window, and the petioles of the protected leaves became curved towards the light as much as those of the unprotected leaves.

Rothert repeated Darwin's experiment on Tropæolum, and found that the leaves reach the right position whether darkened or not. Krabbe also showed by his experiments on Phaseolus and Fuchsia that when the leaf-blades were darkened the leaves reach the right position just as readily and as precisely as the undarkened leaves. On the other hand, Vöchting came to the conclusion from his experiments on Malva that the curvature of the leaf-stalk only followed when the blade of the leaf was illuminated.

Haberlandt concluded from his experiments on a variety of leaves that in some cases the lamina is the only percipient organ, that in others both lamina and leaf-stalk are concerned, and that in very few cases is the leaf-stalk or pulvinus alone responsible. He considers that when both lamina and leaf-stalk are concerned the larger movement is probably brought about by the leaf-stalk and the finer regulating movement by the lamina.

The experiments which I am about to describe are concerned in the first instance with the problem: Does the lamina perceive the light, or is the leaf-stalk the percipient organ, or do both take part in it?

The observations were carried out by a method suggested by the extremely ingenious and charming device employed by F. Darwin to prove that the geotropic sensitiveness of the plumule of a grass seedling is localised at the apex. It consists essentially in keeping the blade of the leaf fixed while the petiole is free to move. Thus if the blade of the leaf is kept in a horizontal position and then exposed to oblique light, what effect will be produced on the petiole? If it is free to move, the petiole ought to curve towards the light; and if the stimulus is localised in the leaf-blade, the curvature ought theoretically to continue so long as the stimulus continues to act and the petiole is capable of growth.

The experiment was first of all tried with a number of leaves of *Eranthis hiemalis*. The leaves were carefully removed from the plant; the blades were then attached to a glass plate, and the stalks were allowed to hang downwards in a glass vessel containing water.

FIG. 2.—*Tropaeolum majus.* Leaf exposed to lateral light and then turned round. The curvature of the petiole becomes reversed.

On exposure to an oblique lateral light the stalks very soon began to curve towards the light, and continued to curve in the same direction for several hours, until in many cases a complete spiral was formed (Fig. 1). Similar results were obtained with the leaves of many other plants. If a leaf in the petiole of which this heliotropic curvature has been induced is turned round so that the light impinges upon it on the opposite side, the curvature becomes reversed (Fig. 2).

The advantages of this method are that the leaves are not submitted to the rough treatment necessary to darken the blades or stalks, and, secondly, there is less interference with the respiratory and assimilatory functions. The disadvantages are that the leaf-stalks, being free to move, may be stimulated by gravity, and the pronounced curvatures thus induced may, unless proper precautions are taken, be mistaken for phototropic curvatures. So long as it is approximately vertical, the leaf-stalk is not influenced, or only slightly, by gravity, but immediately it moves from the vertical in response to the light stimulus, the influence of gravity comes into play, and light in conjunction with the gravitational stimulus takes a share in effecting its curvature. As soon, however, as the leaf-stalk in its upward movement passes beyond the vertical, the gravitational stimulus tends to bring it back to the vertical position, and the light stimulus then, in order to effect any further curvature, has to continue its action against the force of gravity.

A striking experiment to show that curvatures may be effected by the phototropic stimulus against the gravitational stimulus was made by placing leaves upside down. Three young leaves of *Eranthis hiemalis* had their leaf-blades securely fixed between two pieces of black cardboard, the leaf-stalks passing through small holes in one of the pieces of card. The leaves were then placed with the stalks projecting upwards in water in a rectangular glass vessel. Three sides of the glass were darkened, the other side was exposed to a dull lateral light. In the course of the day (Fig. 3) the stalks curved distinctly towards the light against the force of gravity which tends to keep them vertical.

In all these experiments the light was allowed to act upon the whole of the leaf, both blade and leaf-stalk, but as in many cases the leaf-stalk itself is phototropically sensitive, it was important to determine to what extent either of these organs, submitted separately to the influence of light, might bring about the curvature. Accordingly, experiments were made by which the leaf-blades only were exposed to oblique light. This was done by fitting a light tight cover over an opaque vessel containing water. The stalks of the leaves were passed through small apertures in the cover and allowed to hang down in the water. The blades resting on the surface of the cover

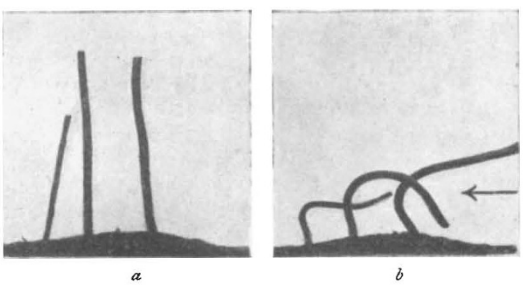

FIG. 3.—*Eranthis hiemalis.* Three leaves placed upside down, with their stalks vertical (*a*); on exposure to light they curved towards it (*b*).

were then covered with a piece of clear glass and exposed to the light. After some time the stalks were found to be curved more or less in different directions, no doubt due to the geotropic stimulus, but there was no definite curvature towards the light, although in many experiments the leaves were exposed to the light for a week and even longer.

When, however, the leaf-stalks are exposed to the light and the blades kept in the dark, the stalks all curve distinctly to the light. A large number of leaves belonging to different families of plants was tested in this way, and the result was always the same. The conclusion therefore seems justified that the perception of light is located not in the leaf-blade but in the leaf-stalk.

The further problem then arises: Does the whole of the leaf-stalk perceive the light or only a portion of it? Have we in the leaf-stalk, as found by C. and F. Darwin in the plumules of seedlings, a percipient region and a motor region separated from one another? To answer this question a simple piece of apparatus was devised, consisting of a shallow box about 10 mm. high, with a thin base and a thin top, leaving a space of about 7 or 8 mm. between them. This was open at one end, and fitted light-tight over an opaque vessel containing water. Through small holes in the top and bottom of the box the leaf-stalks were passed, so that the lower portions were in the dark, the upper 7 or 8 mm. at the apex of the leaf-stalk being exposed to the light. The leaf-blades resting on the upper surface of the box were covered with a piece of black card, and the apparatus was then placed in such a position that light rays entered the box and impinged upon the upper part of the leaf-stalks only. Before the experiment was started, however, in all cases the stalks were allowed to stand for some time in the dark until geotropic curvatures were set up; the position of the leaves was then so adjusted that the darkened parts of the leaf-stalks were all curved in the opposite direction to that of the light incident upon the upper parts.

Under these conditions the heliotropic stimulus was acting in opposition to the geotropic stimulus. The results obtained were most striking. The curvature towards the light was very marked, and distinct spiral curvatures were produced (Fig. 4).

From experiments made in this way on a large number of plants it was found that the apex of the leaf-stalk for a distance of a few millimetres behaves as a percipient region, and is capable of inducing a motor response in the lower part. Experiments were made to determine how much of the apical region it is necessary to expose to the light in order to obtain a response. Leaves of *Geranium pratense* and *Tropaeolum minus* were arranged to allow different

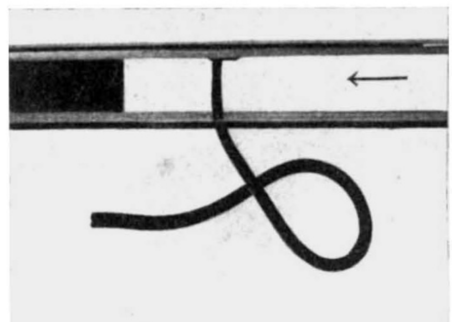

FIG. 4.—*Tropaeolum majus.* Upper 6 mm. of stalk only exposed to light. The direction of the light is indicated by the arrow.

lengths of the apex, 1 mm., 2 mm., 4 mm., 6 mm., 8 mm., and 10 mm. respectively, to be exposed to the light. A distinct response was obtained in each case, but the most definite results were obtained with lengths of from 4 to 10 millimetres.

We have now to consider briefly the mechanics of the movement. The curvature of the stalk is brought about by a more rapid elongation or growth on one side. The tissues of which the stalk is composed are all in a state of strain. The pith and vascular cylinder tend to expand, the cortical tissues to contract. Consequently if the stalk is split down the middle the two halves curve outwards, and, if placed in water, may coil up into a spiral. Now, how does the phototropic stimulus affect this state of strain? What will be the effect of splitting a leaf-stalk that has become curved under the influence of light? Will the two halves coil themselves up in opposite directions as before, or will it be found that the tensions have become modified, and the curvatures also modified in consequence? The experiment was tried on a number of different leaves, and it was found that in all cases the posterior half of the leaf-stalk retains the heliotropic curve, but the end of it tends to coil backwards as before. It is obvious that the light stimulus brings about a permanent change by which the relationships of the tissues to one another as regards their tensions are modified.

Now what will happen if a stalk is split before the heliotropic stimulus is applied? Will the stimulus affect the two halves, or will the posterior half remain unchanged? To investigate this a leaf-stalk of *Geranium pratense* was split to within 8 mm. of the apex. The unsplit part was then exposed to light, the blade and the lower portion of the stalk being kept in the dark. The result shows (Fig. 5) that the stimulus received by the upper part of the stalk is transmitted to both halves, and the posterior half curves in the direction of the light. The end of the posterior half is, however, coiled backwards as before.

FIG. 5.—*Geranium pratense*. Petiole split to within 8 mm. of the apex and then exposed to light; the lamina was kept in the dark.

If we split a stalk into four we get the same result (Fig. 6); all the four separate parts of the leaf-stalk curve quite distinctly to the light.

Now arises the further interesting problem. If the leaf-stalk is split right up to the apex, will any effect of light be produced in the posterior half? A leaf-stalk split up to the apex was immersed in water for some time until a distinct spiral curvature was produced in both halves. The upper 8 mm. of the two halves were then exposed to light, one half being in front of the other, the blade and remainder of the stalk being kept in the dark. At the end of several hours' exposure to light, not only was the anterior half much coiled—due to the heliotropic stimulus and turgescence of the pith acting together—but the posterior half also showed a distinct curvature to the light in the motor region (Fig. 7). We find, therefore, notwithstanding the fact that two halves of

FIG. 6.—*Geranium pratense*.—Petiole split into four. All four parts curved to the light; the lamina was in the dark.

the percipient region, the anterior and posterior, are completely separated from one another, that the posterior half receives a stimulus as well as the anterior half, and that this determines in it a definite heliotropic curvature. Some attempt was then made to determine (1) what tissues of the stalk are concerned in the perception of light, and (2) the tissues through which the stimulus is conducted. In the first place, the epidermis of the stalk was completely removed and the upper 10 mm. of the stalk then exposed to the light, leaving the blade and the rest of the stalk in darkness. After several hours a definite curvature to the light was obtained, although not so pronounced as in an uninjured stalk. This was probably due to the rough treatment to which the stalk had been submitted by scraping off the epidermis. The experiment, however, shows that the epidermis is not essential either for the perception or the transmission of this stimulus.

Another leaf was then taken and the epidermis together with a part of the underlying cortex removed. In this case also, when the upper part of the stalk was exposed to the light, a definite curvature was obtained. Another leaf had the epidermis and the whole of the cortex removed, but in this case, even after an exposure of three days, no definite curvature to the light was obtained. These experiments indicate therefore that the cortical tissues are those mainly concerned in the perception and transmission of the stimulus. Further, several leaves were taken and transverse incisions were made on opposite sides of the stalk so that the tissues were completely cut across. Here also a distinct but not very pronounced curvature to the light resulted. It thus appears that

FIG. 7.—*Geranium pratense*. The petiole was split up to the apex. The posterior half as well as the anterior half curved distinctly towards the light.

although the perception of light is located in the cortex the stimulus can be to some extent transmitted transversally through the tissues, probably through the parenchyma and pith. That the pith is not necessary, however, was proved by splitting the leaf-stalk longitudinally into two halves and then removing by means of a sharp scalpel the whole of the pith, together with some small portion of the vascular bundles. On exposing the upper part of the stalk thus treated to the light, a definite curvature was obtained in both halves of the stalk.

It appears, therefore, from these experiments that the perception of light is located, probably, mainly in the cortex, but that the transmission of the stimulus may be conducted both longitudinally and transversally through any of the parenchymatous cells of the stalk, and that the motor response, although much more definite and pronounced when the whole of the cortex is present, can also take place when this is partly removed.

We may now ask, What is it that the leaf perceives, the direction of the light rays or the difference of intensity and the illumination on the two sides of the leaf? We cannot answer this question decisively; it is probable that both hypotheses are to some extent correct. When the stronger light falls upon one side of the leaf-stalk, those cells on the side which is more illuminated are stimulated to activity to a greater extent than those on the less illuminated side, and the stimulus is transmitted to the motor region. Inasmuch as this stimulus is due to physico-chemical changes set up in the cells nearest to the light, the plant may be said to perceive a difference in the effects produced by the light on the two sides—that is, it is able to compare the two intensities. As soon, however, as the leaf reaches its right position, the apex of the stalk is illuminated more or less equally on all sides, and as the physico-chemical changes in the cells may now be considered to be more or less equal, no further stimulus will be transmitted, or, if so, will be transmitted equally all round the stalk, and no curvature in either direction will take place. The leaf now being placed in a definite position with reference to the direction of the light rays, it would seem quite justifiable to conclude that the plant is capable of perceiving the direction of the rays of light.

But the leaf is also capable of distinguishing between light of different wave-lengths. Notwithstanding the fact that rays of light both at the red end and at the blue end of the spectrum are absorbed, the plant responds phototropically mainly to the rays at the blue end of the spectrum, very slightly, possibly, in some cases to the red rays. This has been demonstrated by keeping plants behind different coloured light filters, and also in different parts of the spectrum. That this power is localised in the percipient region at the apex of the leaf-stalk can be very easily proved by exposing this percipient region to rays of the blue or red colour. The filters prepared and spectroscopically examined by Messrs. Wratten and Wainwright can be used for this purpose. Experiments were made with blue, green, and red filters. A strong curvature took place under the influence of the blue rays, but no curvature under the influence of the green or red rays, even when the exposure was continued for more than a week.

Here we have to do, therefore, with the quality as well as with the intensity and direction of the light rays, and the fact that the plant is more sensitive heliotropically to the shorter and more frequent vibrations at the blue end of the spectrum than to the longer and less frequent vibrations at the red end, indicates that it cannot merely be the direction of the light rays that is perceived. Moreover, we must remember that the plant does not respond directly to the action of light, but to the physico-chemical changes that take place in the photo-sensitive cells of the percipient region. We ourselves perceive the light because the brain is able to translate into sense impressions the physico-chemical changes which take place in the elements of the retina. The plant perceives the light because it is able to translate into a motor response the physico-chemical changes taking place in the photo-sensitive cells of the perceptive region.

We may imagine that in the plant the action is as follows: The light is absorbed by, and excites, certain photo-active substances in the cells of the sensitive region. A stimulus is thus set up which is conveyed through the cytoplasmic fibrils of the protoplasts to the motor region. A further impulse is then set up which acts upon the cells in the motor region, by which it is probable that changes in the permeability of the protoplasts are effected; the turgor conditions of the cells are thereby differentially altered, and the result is a motor response. We have here, in fact, a very simple type of reflex act taking place through the agency not of highly specialised nerve-cells, but of ordinary protoplasm and of the delicate protoplasmic fibrils which extend from one cell to another.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

OXFORD.—Prof. R. B. Clifton, who lately retired from the professorship of experimental philosophy at the end of his fiftieth year of service, has been elected to an honorary fellowship at Wadham College. He has been connected with that college ever since his appointment in 1865, and was an ordinary fellow for the thirty-two years previous to his retirement.

THE Secretary of State for India has appointed Mr. K. Zachariah to be professor of political economy and political philosophy at Presidency College, Calcutta; and Mr. W. A. Jenkins to be professor of physics at the Dacca College.

WE learn from the issue of *Science* for December 3 that objections have been filed to the will of the late Mr. Amos F. Eno, who bequeathed a large sum to public purposes and made Columbia University his residuary legatee. It is said that under the will Columbia University would receive 600,000*l*. or more. Our contemporary also states that a bequest of 10,000*l*. has been made to Cornell University by Mrs. Sarah M. Sage to promote the advancement of medical science by the prosecution of research at Ithaca.

WE have received from Washington a copy of a timely volume prepared by Mr. S. P. Capen, specialist in higher education of the United States Bureau of Education, entitled "Opportunities for Foreign Students at Colleges and Universities in the United States." Students of education will find in it an excellent account of the present facilities for higher education in the States. Every kind of information that an intending student can require is provided. Prominence is given to descriptions of the organisation of a typical American university, living conditions, college life, and college entrance requirements. With reference to the expenses of foreign students, Mr. Capen points out that these vary widely at different institutions. Practically all the privately endowed institutions charge annual tuition fees. The fee is rarely less than 8*l*. a year for collegiate instruction, and in some cases is as high as 30*l*. or 40*l*. a year. Professional instruction, particularly in medicine and engineering, is still more expensive. The Massachusetts Institute of Technology charges 50*l*. a year, and to its students in naval construction and naval architecture 100*l*. a year. Most State-aided institutions charge only a small tuition fee to collegiate students not resident in the State, State residents being generally given free instruction. Living expenses, aside from tuition and other fees, vary with the location of the institution. As a rule, the fundamental charges—room, board, and laundry—are rather lower at country institutions than at those in the cities. The possible wide variations in price are indicated by the figure 18*s*. quoted as the weekly minimum by the University of Minnesota, and 2*l*. 8*s*. the weekly maximum mentioned by Cornell University. The incidental expenses of city living, including amusements, should, of course, also be reckoned.

ON December 9 Mr. Patrick Alexander, well known by his pioneer work in aeronautics, made over to the headmaster of the Imperial Service College, Windsor (Mr. E. G. A. Beckwith), the munificent sum of 10,000*l*. "for the furtherance of the education of boys of the Imperial Service College, *i.e.* for the training of character and the development of knowledge." Mr. Alexander had given to the college an aero-laboratory and equipment about five years ago, but owing to long absences abroad, and a serious illness, he has been unable to identify himself with the college of late as heretofore. Having, however, taken up his residence in Windsor for the last six months, he has been able to continue his research work in the labora-