Modern Developments in the Design of Aeroplanes*

Scientific Research and the Problems of the Future

PREVIOUS James Forrest lectures summing up the then situation in aeronautics were delivered by Dr. F. W. Lanchester in 1914 and Prof. R. V. Southwell in 1930. It is curious that the scientific development of the aeroplane has fallen into phases that appear to correspond with these dates. From 1914 until 1930, the aero-engine made the more marked progress, but since that date advances in aerodynamic efficiency of aircraft have been the outstanding achievement. General aerodynamic improvement has been compounded of a number of more or less independent steps: better shapes of wings and bodies; smoother surfaces and the elimination of discontinuities in those surfaces; reduction of excrescences; closing over of openings such as cockpits; retraction of undercarriages; and improvements in means of engine cooling.

Comparing the De Havilland "Comet" and the Heinkel "He 70", the outstanding machines of 1935, with a good example of 1930 design, the drag coefficients for wing area and total 'wetted' area of the whole machine have been reduced to less than half their best value in 1930. The combination of this reduced resistance with higher powered modern engines has raised speeds from 170 miles per hour, quoted by Southwell in 1930, to more than 300 miles per hour to-day.

A great deal of this advance has been due to a more complete appreciation of the basic problem of aerodynamic effects, consequent upon the introduction of the compressed air wind tunnel. This has enabled phenomena to be studied over the whole range of Reynolds numbers, between that in an ordinary atmospheric tunnel, and that of full-scale flight. A typical case of this kind is that of the effect of surface roughness on drag, from which it has been established that, at speeds now reached, the surface roughness, due to the almost universal practice of covering aircraft wings with fabric, has an effect large enough to be intolerable.

This increase in top speed has brought its own problem, in that the minimum speed at which the machine will remain air-borne, that is, the landing speed, may not rise with it, because of safety requirements during landing and taking off. Handley Page slots, or trailing edge flaps, although their effect is basically different, both have the desired effect of delaying the 'stall' to safe speeds, and the appropriate use of either one, or a combination of both, appears to give such extra speed range as is necessary.

Another problem that has been attacked since its physical basis has become better understood is that of 'interference'. For example, the combination of a body and a wing, both separately of low drag, in such relative positions as practice demands for a low-wing monoplane, may give in total a high drag due to interference. It has been improved by filling in the regions of divergent flow with 'fillets'. The extra advantages due to having a short, easily retracted undercarriage, and the improved landing conditions due to the 'cushioning' of the air beneath a wing, close to the ground, more than compensate for the little remaining aerodynamic inferiority of this over other arrangements of wings and bodies.

Great advances have also been made in the problem of engine cooling, and the state of knowledge is now such that even further progress may be expected in the near future. The liquid-cooled engine may use retractable radiators, drawn progressively inside the body at higher speeds or when the temperature of the air falls, when the cooling is more effective. Alternatively, portions of the aeroplane's surface may be given a double skin between which a thin layer of liquid circulates, as developed for the machines in the Schneider Trophy race, which gives cooling for practically no drag. For air-cooled engines the "Townend Ring" and the "N.A.C.A." cowling can now be so designed that they not only give properly distributed and controlled cooling to the engine, thus increasing its efficiency, but also it is possible to visualise the exhausted cooling air being so directed that it adds to the propulsive force of the airscrew. Thus a cooling drag of a negative value will be possible, as compared with 6–10 per cent of the brake horse-power of the engine lost in measured cases of fairly recent machines.

Improvement of the airspeed of flying-boats and seaplanes is hampered by the necessity for good water performance. The best shape of floats and hulls for landing and taking off does not usually give low air drag. Further, either wing tip floats or stub wings are needed to give stability when afloat, and these are not so easy to retract as the corresponding undercarriage of a land machine. A certain part of this inevitable inferiority in performance is regained in that such a machine has

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larger surfaces from which to manœuvre, and consequently can have a higher minimum speed.

This increase of top speed, coupled with the extension of speed range, has brought many minor troubles that have called for special scientific investigations. The difference between minimum 'take-off' speed and normal 'cruising' speed is now so marked that a variable pitch propeller is necessary if maximum efficiency is demanded under all conditions. This has proved to be practicable in metal, but up to now is about three times the weight of a fixed pitch wooden airscrew. Servo-assisted controls are often necessary on both large and fast machines, and the correct relationship between aerodynamic balance, servo-action and manual operation of the various control surfaces, and their correlation with each other, is not easy to establish.

Considering the future, there are three main lines of progress: further reduction of drag, reduction of structure weight and improvement in engine performance. The margin between the present attained minimum drag and pure skin friction is small, and no great improvement in this is likely unless some revolutionary discovery points to a means of compelling the boundary layer flow to remain laminar over a much greater portion of a surface. Also as the speed of a body approaches the speed of sound in air the effect of compressibility causes a rapid rise in drag. The world's speed record is already six-tenths of the speed of sound. The problem of cooling will also be complicated by the natural rise in temperature of a body moving rapidly through air. Reduction of structure weight of a large order does not seem probable, unless research in atomic physics brings the production of synthetic materials with properties vastly superior to those in use at present. Improvements in engine performance will only be of a detailed order, unless something revolutionary in the manner of converting the latent energy in fuel into power is discovered.

Light and Temperature and the Reproduction of Plants*

By Prof. V. H. Blackman, F.R.S.

THE path of the plant physiologist who sets out to make accurate measurements of the effect of light and temperature on the growth and multiplication of the plant is beset with many hindrances. In the first place, the plant, the system which he investigates, is never completely reproducible. No two living things are exactly alike, and the variability of the biologist's material is an ever-present threat to the accuracy of his work. Something can be done to reduce the variability by selecting the progeny of a single individual, using clonal or pure-line plants. After the most careful selection, however, some variability inevitably remains; this must be evaluated by statistical methods.

EFFECT OF LIGHT

With the study of the influence of such an external condition as light, other difficulties arise. Sunlight, as we receive it, is inconstant in quantity and variable in quality. In exact studies of the action of light which are to last for more than the briefest period, one must inevitably resort to artificial sources of illumination, since they alone can be held constant for long periods. Unfortunately, electric light sources, though wanting nothing in steadiness, are very different from sunlight. No illumination engineer has yet achieved the 100 per cent efficiency of the 'cold' light of the glow-worm which includes no heat rays. Caution must therefore be exercised in applying to plants grown under natural conditions the physiological results obtained with artificial light sources.

Although in experimental work the constancy of the illuminant can be assured by the selection of artificial light, the uniformity of illumination of the whole plant surface is much more difficult of accomplishment. If the light source is removed so far from the plant that its upgrowth results in no marked difference of intensity between the upper and lower portions, then the illumination received is generally of too low intensity. When considering this difficulty some ten years ago, it was evident that the need was for a plant which had no upward growth but spread only horizontally. It was then realised that, in the ordinary duckweed (*Lemna minor*) of our ponds, Nature has provided such a plant. From that time onward, the physiological behaviour of this plant has been intensively studied in the laboratories of the Imperial College of Science.

By placing the plant under carefully controlled conditions, a regular, continuous growth can be

* Substance of the Friday Evening Discourse delivered at the Royal Institution on February 21.