Table 1. Ratio of phosphorus-32 concentration in apical segments of barley roots to that of the initial culture solution

Phosphorus-32 content of culture solution (initial)	Level of total phosphorus in culture solution (milli-equivalents-H_2PO_4/litre) 2	1	10^{-3} or less		
μC./litre	*b*	*a*	*a*	*b*	*c*
1·5	32			1420	1270
5	28	50	1370	1180	1100
10		50	1430		1680
15	20			980	
20		70	730		
50		18	300		
Mean	27	50		1130	

a duration of experiment 6 days
b ,, ,, ,, 4 ,,
c ,, ,, ,, 1 day

the observed effects. We have determined the radioactivity of the apical 0·5 cm. of roots and compared this with the initial activity of the culture solutions in three experiments (Table 1). At high levels of total phosphorus (1 or 2 milli-equivalents-H_2PO_4 per litre) accumulations of 20–70 times the initial external concentration are shown, while at low levels of total phosphorus (10^{-3} milli-equivalents or less) the average accumulation exceeded 1,100. This high level is reached within twenty-four hours of treatment, and there is some indication that accumulation is reduced in consequence of radiation damage. Calculations have been made of the radiation dose-rate in rontgens equivalent physical (reps.) per day for the initial culture solutions and the root tips[6] (Table 2). Allowance has been made for the dimensions of the root tips being less than the range of β-particles[7]. For the purpose of this correction the root tips, the average volume of which was 0·7 $mm.^3$, have been treated as spheres. Since it is known from radio-autographs that phosphorus-32 was not evenly distributed in the meristems, the maximum dose-rates will exceed the figures shown. The approximate nature of these calculations must be emphasized, but they indicate that, although the radiation dose-rate in the culture solutions was very low, the root tips of the low carrier treatments in which radiation damage was observed received 300 reps./day. In high-carrier treatments damage has been established at dose-rates of 20–29 reps./day. Parallel cytological investigations have not yet been carried out, but there is evidence from the literature that equivalent total dosages from external radiation sources significantly affect nuclear division[8]; though, since different dose-rates were employed, the results are not strictly comparable. There is also some evidence that similar total radiation levels from phosphorus-32 affect cytoplasmic viscosity and absorption[9].

The present results show that radiation damage may be a much more serious hazard in tracer experiments than the literature led us to expect. Significant radiation effects have been observed when the level of phosphorus-32 is 10 μC./litre. Since radiation damage under these conditions is occasioned by the accumulation of phosphorus-32 within the plant, the level of tracer at which injury occurs will vary between experiments according to the rate of nutrient accumulation of the plants, the level of carrier, and the duration of the experiment. Rapidly growing young plants, such as those we have worked with, should be more easily damaged than older and less active material. This may, perhaps, be the explanation for the difference between Arnon's[1] and our own findings, since his experiments were carried out on tomato plants at an advanced stage of growth. Similarly, much higher levels of phosphorus-32 may be expected to cause no biological effects in experiments lasting a short time, for example, those of Overstreet and Jacobsen[10].

Table 2. Radiation dosage in the initial culture solution and in the root tips in the experiments shown in Table 1
Rontgens equivalent physical/day

Phosphorus-32 content of culture solution (initial) μC./litre	Culture solution	Root tips: Level of total phosphorus in culture solution (milli-equivalents-H_2PO_4/litre) 2	1	10^{-3}
1·5	0·06	1·0		40
5	0·2	2·8	5	120
10	0·4		10	300
15	0·6	6·0		300
20	0·8		30	300
50	2·0		20	300

Although these findings do not indicate any obstacles to the use of tracers in plant studies which cannot be overcome by careful techniques, the conclusion is inescapable that in general the hazard of radiation damage has not been sufficiently realized. The absence of any change in the weight of the above-ground parts of plants does not constitute a valid proof that radiation damage has not occurred, an assumption made by Hendricks and his co-workers in their extensive investigations[3]. The value of the results of any tracer investigation is doubtful unless the absence of radiation damage is established—and at the present time this can be done only by the careful analysis of plants treated with varying levels of radioactivity under the conditions of the experiment. Further work should, however, permit less laborious methods to be employed.

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ROTARY WING AIRCRAFT

INTEREST in Great Britain in rotating wing development has been particularly marked in recent months not only as a result of the establishment of a new helicopter speed record by a British machine, but also because for the first time there are several British helicopters being designed, built and flown. It was, therefore, in a mood of optimism that a large audience, including several well-known French exponents, gathered at the Institution of Civil Engineers on November 20 to hear a series of lectures on helicopter problems with particular emphasis on civil use, given by some of the leading British technical workers and designers in this field. The meeting was a joint one of the Royal Aeronautical Society and the Helicopter Association of Great Britain, all the papers being provided by members of the latter body.

The first paper was read by Wing Commander R. A. C. Brie, the well-known auto-gyro and helicopter pilot, on "The Operational Point of View". He presented the results of two years on operations using Sikorsky helicopters in Great Britain; classifying the problems into three broad groups, engineering, flying and operational characteristics, he covered the wide field of the actual use of the helicopter. He pointed out that many of the factors tending to reduce the utilization of fixed wing aircraft are more than ever applicable to helicopters, both because of the mechanical complexity and the need for compactness, and advocated the use of easily removable units and improved accessibility. The need for special tools and extractors required to permit easy breakdown and assembly was also emphasized.

Referring to the problems of flying, Wing Commander Brie emphasized the difficulties associated with night- and blind-flying, and the necessity for achieving slow rates of descent in autorotation. He stressed the importance of safety both for ground use and flying personnel. Pointing out that at present helicopters cannot be used economically except for special purposes, he gave his views on the need for comfort for passenger machines and the necessity for low vibrational- and sound-levels. He particularly stressed that the twin-engine types would eventually appear as the standard machine, particularly for operation over populated routes.

The second speaker was Capt. R. N. Liptrot, who discussed the technical problems of the civil helicopter. He dealt with the conventional problems of vibration and stability, and pointed out that although the use of flapping hinges relieves the periodic bending moments due to the varying lift forces, and drag hinges relieve the Coriolis moments induced during flapping, there are left hunting oscillations due to the fact that one of the natural frequencies of oscillation about the drag hinge is of the same order as the rotor rate of rotation. He also referred to the effect of tip stalling in producing additional vibration, and expressed the view that vibration rather than the compressibility effect may eventually be the major factor in limiting the forward speed of helicopters. He spoke at length about the problem of stability, remarking that the characteristics of most single rotor machines are still inadequate, and stressing the need for improvement. It is a pity that time did not permit him to refer to the work being done in Great Britain by Dr. G. J. Sissingh and his associates on automatic stabilization (which formed the subject of a lecture and discussion at a recent meeting of the Helicopter Association).

Capt. Liptrot referred to the difficulty of flying resulting from the use of an additional control, namely, the collective pitch control, and advocated the simplification of controls. This point is of particular interest in view of some of the claims made later for the Fairey gyrodyne. He pointed out that there is a danger zone between an altitude of 300 ft., above which autorotative descent is possible, and 50 ft. altitude, below which an increase of collective pitch facilitates safe landing. The reduction of this zone is of major importance and no doubt great effort will be expended in the future in this direction.

On maintenance questions, Capt. Liptrot referred to the troubles arising as a result of friction oxidation or 'false Brinnelling' occurring in oscillating bearings, such as those used for flapping- and drag-hinges, where the angular range used is limited. The engine installation of some of the early types of helicopters was far from satisfactory. It is important at the present time that parts be designed for longer life, longer periods between inspection and greater simplicity everywhere.

During the afternoon, three eminent designers of helicopters expressed the point of view of the constructor's reaction to helicopter problems.

The first, Dr. J. A. J. Bennett, whose long association with rotary-wing aircraft is particularly noteworthy, gave some details of the Fairey gyrodyne. This machine is undoubtedly one of the most advanced technically of any of the helicopters flying to-day. It incorporates all the usual vibration palliatives such as $\delta 3$ hinges, flexible blades of low solidity, high torsional blade stiffness, hydraulic dampers imposing little constraint and, typical of this type of lay-out, a tip-path plane maintained parallel to the direction of motion in forward flight, thus avoiding the periodic tip stall. What vibration is left is eliminated from the controls by the use of a hydraulic irreversible system, without doubt a step forward in control design.

Probably the most interesting engineering feature of the design is the elimination of the fourth control by means of an automatic pitch-change unit, the lag angle in azimuth associated with a varying torque resulting in a variation in blade-angle setting. Stability is achieved in forward flight by the use of a tail plane, and since the aircraft is specifically designed for fast forward motion, the resulting characteristics are very satisfactory.

Dr. Bennett did not say whether he had considered the possibilities of using flaps on the short stub fairings, and it would have been interesting to have heard his views on this point.

The second speaker of the afternoon was Mr. Raoul Hafner, whose reputation in this field is international. He discussed the particular features of the Bristol 171 helicopter, which were of interest in view of the earlier remarks made by Wing Commander Brie and Capt. Liptrot. He concentrated chiefly on the problem of vibration. His approach was to analyse the feathering motion of a rotor blade in the form of a Fourier series, the coefficients of which can be associated with the physical and aerodynamic characteristics of the blade. For small tip-speed ratios, only the first harmonic is of importance; with larger tip-speed ratios, the higher harmonics become predominant, resulting in vibration, since the difficulty of supplying a suitable linkage to compensate for these is great. Defining the mean lift coefficient by means of the formula

$$C_{L\ \text{basic}} = \frac{\text{blade lift}}{\frac{1}{2}\rho\omega^2\int_0^R cr^2 dr},$$

the lift coefficient in translational flight can be related to this coefficient, and a limiting value of the tip-speed ratio exists given by

$$\mu_{\text{lim}} = \frac{3}{4}\left[1 - \sqrt{\frac{C_{L\ \text{basic}}}{C_{L\ \text{max}}}}\right],$$

indicating that a high tip-speed ratio is only possible when the basic lift coefficient is small. This can be interpreted as a speed limitation, and when combined with the speed limitation due to critical Mach number for the aerofoil at the blade tip, a possible operating regime is determined.

Mr. Hafner analysed also the forces acting in the plane of rotation of the rotor blade, and pointed out that the two major forces are those due to profile drag of the blade and the components of the lift vector in the plane of rotation. The reduction in the coning angle of the blade is favourable to drag reduction, and by a suitable choice of design parameters, it is possible to balance the drag variation due to inflow conditions by the variation in profile drag, the result being a general lowering of the level of vibration.

On the question of controls, Mr. Hafner indicated that there is a very great need for simplification, and asserted that four controls represent the minimum number. The possibility of reducing complexity was illustrated by the fact that there are only twenty-seven moving parts in the rotor control mechanism of the Bristol 171.

On the question of stability, Mr. Hafner felt that stability in forward flight is of much greater importance than hovering stability, and that all that is required in the latter direction is that the helicopter should not be unduly unstable. He spoke at length of the problems of the danger zone referred to by previous speakers, and showed some auto-observer records of descent made in the Bristol 171, which indicated the degree of safety of this aircraft. He closed with some remarks on the question of capital and maintenance costs. He said that these could be reduced by means of good design and that it had been possible for all wearing parts on his machine to be designed for a life of 7,500 hours without great sacrifice in weight.

The last lecturer was Mr. J. Shapiro, who spoke about the Cierva Air Horse. This machine, which is remarkable in many respects, is based on the principle of three lifting rotors. In view of the apparent complication and possible high structure weight of the Air Horse, Mr. Shapiro was faced with the somewhat difficult task of stating its merits which, he claimed, include powerful control in roll and pitch independent of total lift, static stability, dynamic stability in hovering and forward flight, low vibration, ground stability, simple access and, perhaps most important, insensitivity to the position of the centre of gravity when fully loaded. Although these are very desirable, it is difficult to see how the trebling of lifting units and their component parts can have anything other than an adverse effect on the maintenance and utilization of the machine. Since the flying characteristics of the machine have not yet been publicized, it is also difficult to say whether this type of lay-out will achieve all the claims made for it; but as Mr. Shapiro pointed out, in the absence of quantitative information on the value of the desirable characteristics per hour of maintenance, there is little doubt that many of the adverse criticisms springing to mind may be somewhat unjustified.

The discussion which followed the various speakers was of a high order, and perhaps the most interesting point made was the correlation between the accident rates in the United States and the insurance premiums in England. It seems difficult to appreciate that faulty training or the irresponsibility of pilots in America should adversely affect the insurance rates in Britain. Potential operators in Britain are somewhat concerned over this matter—apart from the fact that at the present time they have no British aircraft to operate. The use of helicopters for crop dusting was referred to in the course of discussion, although no one referred to the success or otherwise of the project. It is possible that much that has been said on this question is wishful thinking, and in the absence of more specific information it would seem that much development is required before success in this field is attained.

HENRY ROBERTS

CONTROL OF EQUILIBRIUM IN THE FLYING INSECT

THE higher Diptera, comprising such insects as the house-fly, the blow-flies and the hover-flies, have remarkable powers of controlled flight. The studies of F. S. J. Hollick[1] on the aerodynamics of dipterous flight showed that these insects are inherently stable in pitch, alterations in attitude being corrected automatically by a change in the amplitude of the wing beat. There is some suggestion also of inherent stability in the rolling plane, but nothing to indicate stability in yaw. In general aerodynamical terms, the fly probably shows what is known as 'spiral instability'. The lower Diptera, such as the gnats and daddy-long-legs, have long thin abdomens, which must increase their inherent stability. Inherent stability, however, is a definite hindrance to the making of rapid turns. In the higher forms the abdomen becomes short, and aids to flight in the form of organs of equilibrium become more efficient.

G. Fraenkel and J. W. S. Pringle[2] suggested that such organs of equilibrium are to be found in the oscillating halteres, the modified hind wings of Diptera, which they supposed to act as alternating gyroscopes. Consequently, if the insect is rotated out of the plane of their vibration, lateral shearing forces will be set up in the cuticle at the base and will stimulate the numerous campaniform sense organs that occur there. In ignorance, apparently, of these suggestions, J. Nageotte[3,4] also put forward the hypothesis that flying Diptera control their equilibrium by the perception of the gyroscopic strains in the halteres.

J. W. S. Pringle[5] has now presented a detailed study of the gyroscopic mechanism of the halteres. Dynamical analysis of the oscillating system shows that when the fly as a whole is not rotating, the only forces acting on the basal region of the haltere are the primary torques about the main hinge. When it is rotated in any plane not that of the oscillation, gyroscopic torques are set up at the base of the haltere about an axis at right angles to the plane of oscillation. Physical considerations render it improbable that these gyroscopic torques in the halteres will afford useful information with regard to pitching and rolling rotations. It is only in the yawing plane that the sense organs are likely to give exact information. Flash-photographs of the fly deprived of its halteres confirm that it is, in fact, in that state of spiral instability which is to be expected if there is inadequate stabilization in the yawing plane.

A re-examination of the sense organs at the base of the haltere, and oscillographic records of impulses in the haltere nerve while the haltere is in a state of natural oscillation, provide good support for these conclusions. When there is no rotation of the body of the fly, impulses are recorded which probably result from excitation of the sense organs of the 'scapal plates' and the 'Hicks papillæ' by the primary forces of oscillation. These organs seem to be excited