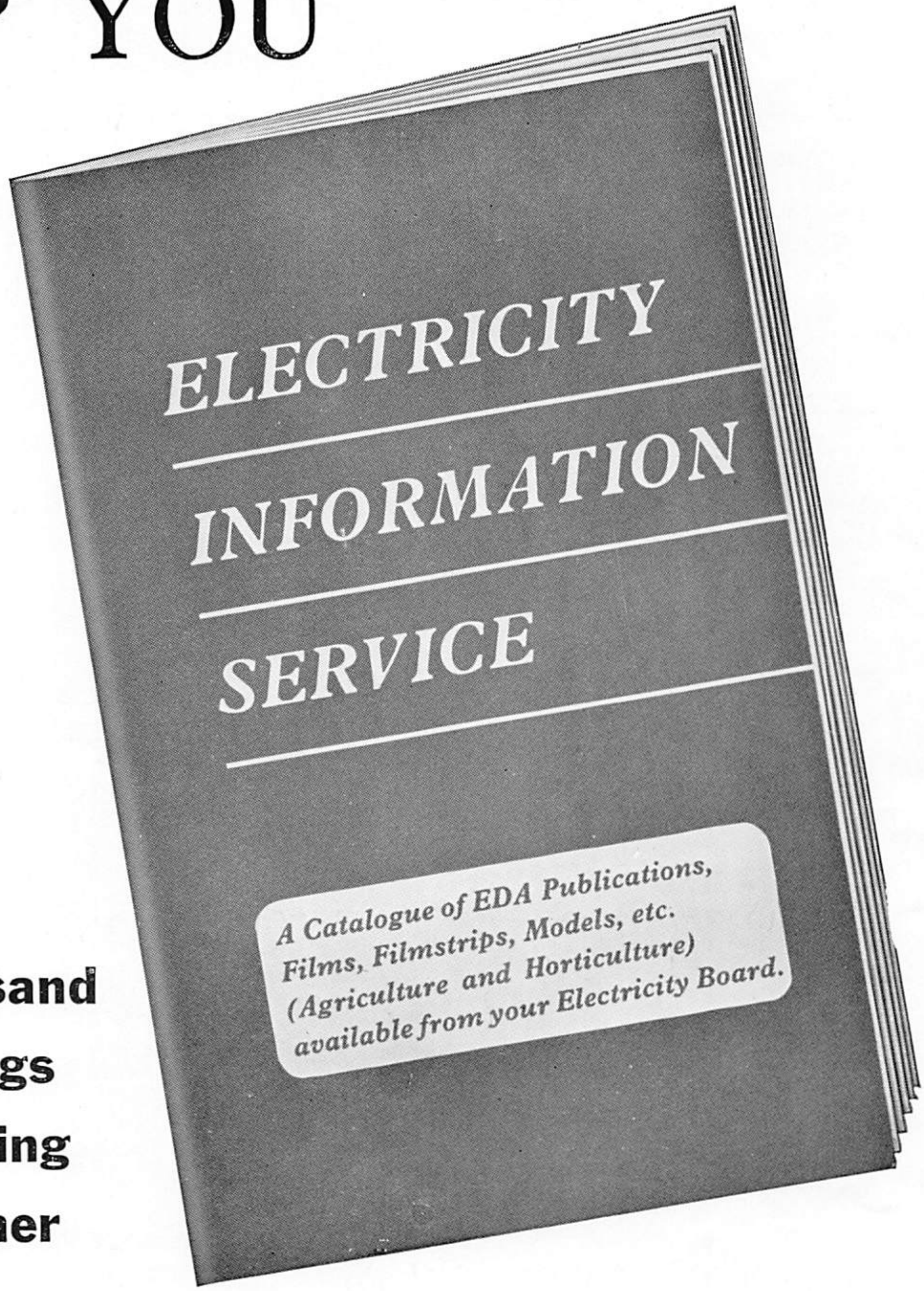
JOURNAL AND PROCEEDINGS OF THE

INSTITUTION OF AGRICULTURAL ENGINEERS

VOL. 18 NO. 3 - AUGUST 1962

ELECTRICITY CAN HELP YOU



Electricity does a thousand and one things to help farming and the farmer

The Electricity Information Service booklet describes the publications, films, scale models and filmstrips which give information on electricity in Agriculture and Horticulture. They deal with everything from crop drying to pig rearing, poultry husbandry to cold frames. *There's bound to be something there which can help you.*

The booklet, and the material listed in it, is available through your Electricity Board or direct from the Electrical Development Association.

ELECTRICAL DEVELOPMENT ASSOCIATION

(JA/Ra), 2 Savoy Hill, London, W.C.2. Telephone : TEMple Bar 9434

JOURNAL AND PROCEEDINGS OF THE INSTITUTION OF AGRICULTURAL ENGINEERS

VOLUME 18 - NUMBER 3 - AUGUST, 1962

CONTENTS

Published by the Institution of Agricultural Engineers, 6, Queen Square, London W.C.1
Telephone : Terminus 0140

Price : Ten Shillings and Sixpence

Published Quarterly

Now Massey-Ferguson add a differential lock (as optional extra) to a long list of features that have made the MF 35 today's biggest-selling tractor. Another good reason why the MF 35 will continue to be the farmer's first choice.

MASSEY-FERGUSON

Salisbury

dependability in transmission . . .

All over the world tractors, dumpers and commercial vehicles, as well as many of the world's finest and fastest cars, rely on Salisbury hypoid axles and gears, for complete dependability in transmission.

The Salisbury Range

The wide range now available includes hypoid and spiral bevel types up to 24″ diameter, generated and revacycles straight bevel gears, hypoid driving and driving/steering axles, hypoid independent drive units—and of course the famous POWR-LOK.

Designers and Engineers are invited to co-operate with Salisbury engineers at the project stage.

SALISBURY *hypoid* **AXLES** | Member of the **Birfield Group**

SALISBURY TRANSMISSION LIMITED · BIRCH ROAD · WITTON · BIRMINGHAM 6

A FARMER'S BEST FRIEND IS A **FORD** ENGINE

Agricultural equipment powered by a Ford Industrial engine starts with two major advantages—the heart of it is a tough, hard-working, reliable power-unit built to the most modern designs, and behind it is the famous Ford Service Organisation—a world-wide chain of factory-trained engineers with stocks of genuine Ford parts.

Self-propelled Combines, Sprayers, Driers, Pumps, etc.—all are available with Ford power-units, petrol or diesel.

Please send the coupon below for details of the Ford-powered equipment you are interested in.

FORD

SPELLS POWER

Please send me details of Ford-powered equipment of the following types

Type or class of equipment ....

NAME ....

ADDRESS ....

....

Ford

TO: **FORD INDUSTRIAL ENGINE DIVISION** · DEPT. G5b/F 15 · SOUTH OCKENDON · ROMFORD · ESSEX · ENGLAND

INSTITUTION NOTES

The views and opinions expressed in Papers and individual contributions are not necessarily those of the Institution. All Papers in this Journal are the copyright of the Institution.

Annual General Meeting

SOME 150 members attended the Annual General Meeting, held at the Royal Society of Arts in May last.

The President (Mr. W. J. Nolan), in presenting the Report of the Council for 1961, referred in particular to the decision to alter the arrangements for Open Meetings in London, the Council having thought that members would prefer an arrangement whereby three Papers would be presented in a whole day, instead of the present one-Paper evening meetings. There would be three such Open Days, and the programmes would be so arranged that there would be ample time for discussion on the Papers and for members to meet socially. Meetings would be timed to end at 5 p.m.

Mr. Nolan expressed the thanks of Council for the work undertaken by the Branches during the year. He had been to a number of Branch Open Meetings and had been impressed by the enthusiastic atmosphere and particularly by the attendances, which on the average were remarkably high.

In presenting the Income and Expenditure Account and Balance Sheet for 1961, the Hon. Treasurer, Mr. A. T. Gilling, pointed out that the continual rise in printing costs, together with an enlarged editorial content, was responsible for a larger net cost in 1961, but the Council was convinced that its quality must be maintained and, as soon as possible, improved as an important service to members.

The position would be very much eased if further advertising space could be sold, and he hoped any members in a position to do so would help in this connection.

The costs of general administration had been kept approximately to the figure of the previous year, the one exception being the item for salaries. In his opinion, the Institution's affairs were being conducted on a very economic level, but costs of everything continued to rise, and it was essential that income should rise at no less a rate.

Mr. Gilling said he hoped that at the end of his next and last year of office he would be able to present an account showing a small surplus, or at least breaking even, but there was no doubt that, for the long term, careful consideration would have to be given by the Council to the improvement of finances.

The Accounts and Balance Sheet were adopted.

The President, before calling on the Secretary to announce the names of the Council for 1962–63, referred to the retiring members and expressed appreciation of their services. After the new members were announced, Mr. Nolan vacated the office of President and handed over the badge of office to Mr. Cameron Brown, the incoming President.

From the body of the hall, Mr. Douglas Bomford then proposed a vote of thanks to Mr. Nolan, who had, he said, been a great President of the Institution. During his term of office the Institution had strengthened itself in every activity. Mr. Nolan's leadership had been characteristic of him—to lead without force or bitterness was the highest quality of leadership, and that was what he had given.

Mr. Nolan was given a standing ovation.

Messrs. Gimson & Co. were appointed auditors for 1962.

Under any other business, Mr. J. H. W. Wilder asked that at future Conferences more time be allowed for discussion after the presentation of Papers.

Mr. G. A. Iles hoped that whatever economies were necessary to meet rising expenditure, the standard of the Journal should not be allowed to fall ; he would sooner see an increased subscription introduced.

Mr. Wilder then said that if there was to be no saving on the Journal, and if examination and administrative expenses could not be cut further, as seemed to be the case, then the present financial position would continue. He asked whether it would help if members said they were prepared to accept an increase in subscriptions ?

The President thanked Mr. Wilder and asked for the views of members present. The consensus of opinion was that, in view of rising costs and the necessity to establish a reserve fund, an increase might be inevitable. There was, however, agreement that if this step were taken student members should receive special consideration.

Mr. Cameron Brown then reminded members that, should any increase become necessary, the income tax concession received since subscriptions were raised in 1956 would in effect retain rates at the earlier level.

Institution Notes Continued on page 105.

ASPECTS OF COMBINE-HARVESTER DESIGN

by P. HEBBLETHWAITE,* M.S., B.Sc., N.D.A., A.M.I.Agr.E., and R. E. ARNOLD,† M.A.

(*A Paper presented to the East Midlands Branch on Wednesday, 21st February*, 1962.)

Introduction

A DETAILED treatment of the subject of combine-harvester design is clearly impossible in a single paper, and thus only selected points will be discussed at any length. References where appropriate are made to the literature, but it is important to point out that except in so far as commercial practice is frequently cited, no mention is made of the vast amount of development work which has been put in over the years by combine-harvester manufacturers. From many points of view it can be argued that it is unfortunate that this fund of knowledge has remained confidential, certainly it has resulted in duplication of some work whilst there are still avenues of research which are unexplored, or at least have not been subjected to a fundamental treatment.

Principles of the Rasp Bar Drum

Relatively few methods of threshing were tried before the introduction of the rasp bar drum, and it has continued basically unchanged up to the present day.[1] Its principles of operation have only been fully appreciated for a very short time, and only in the light of these recent discoveries has it been possible to assess its potential fully.

Before the work of Schulze,[2] which involved the use of high-speed cinephotography (3,200 frames/sec.), theories on the way the drum worked had to be based on simple observation of its action and its effects on the crop being threshed. In view of the speed at which a drum works, it is not surprising that comprehension was incomplete and some of the conclusions incorrect. Perhaps the most important mistake was the assumption that the beater bars rubbed the grain out against the concave, and that the ribs, alternating in direction on the bars, rubbed first one way and then the other to produce an action similar to rubbing grain from an ear by hand. It was also commonly held that the crop was threshed against a mat of straw moving between the beaters and the concave. But neither of these theories is completely true. In the first place the drum will work if the clearance between the beaters and concave is too wide for an ear to make contact with both at the same time, and, in the second, the mat of straw in the drum during threshing is frequently too thin to provide an effective backing against which the beaters can work (Fig. 1).

The basic principle on which the drum in fact relies is the shattering action of the fast-moving beaters on the relatively slow-moving crop. This is a random process, each ear receiving an indefinite number of impacts before threshing is complete. An appreciation of this principle has gone a long way to explain why particular adjustments to the drum have the effect they do, and has made it possible to choose settings more wisely.

Although it is possible for the beaters to nip ears against the concave when the clearance is small, the primary function of the concave is to present the crop to the beaters so that they can work on it in the way outlined above. It must ensure that the crop remains in this position long enough for threshing to be completed. This essential braking action on the straw passing through the gap is provided by the concave bars.

Threshing drums, whether as part of stationary machines or combine-harvesters, have relied on these principles for nearly a century, but there have been numerous variations in the basic design.

Of the various deviations from the conventional metal rasp bar drum and " grate " or " open " concave that have appeared, most have been aimed at reducing grain damage and at the same time maintaining or increasing threshing efficiency. Compounds of a rubbery nature have been used on the beater bars and/or on the bars of the concave in an attempt to reduce grain damage. In some conditions this may have been effective to some extent, but the practice has now been largely discontinued and no resilient material has been able to stand up to threshing without suffering a high rate of wear. Concaves have been made with varying " degrees of openness " ; for cereals any extra threshing efficiency that may result from closing a concave appears to be offset by the increase in grain damage (Table I) which results due to the fact

* Head of Implement Testing Department, N.I.A.E.
† Harvesting and Handleling Department, N.I.A.E.

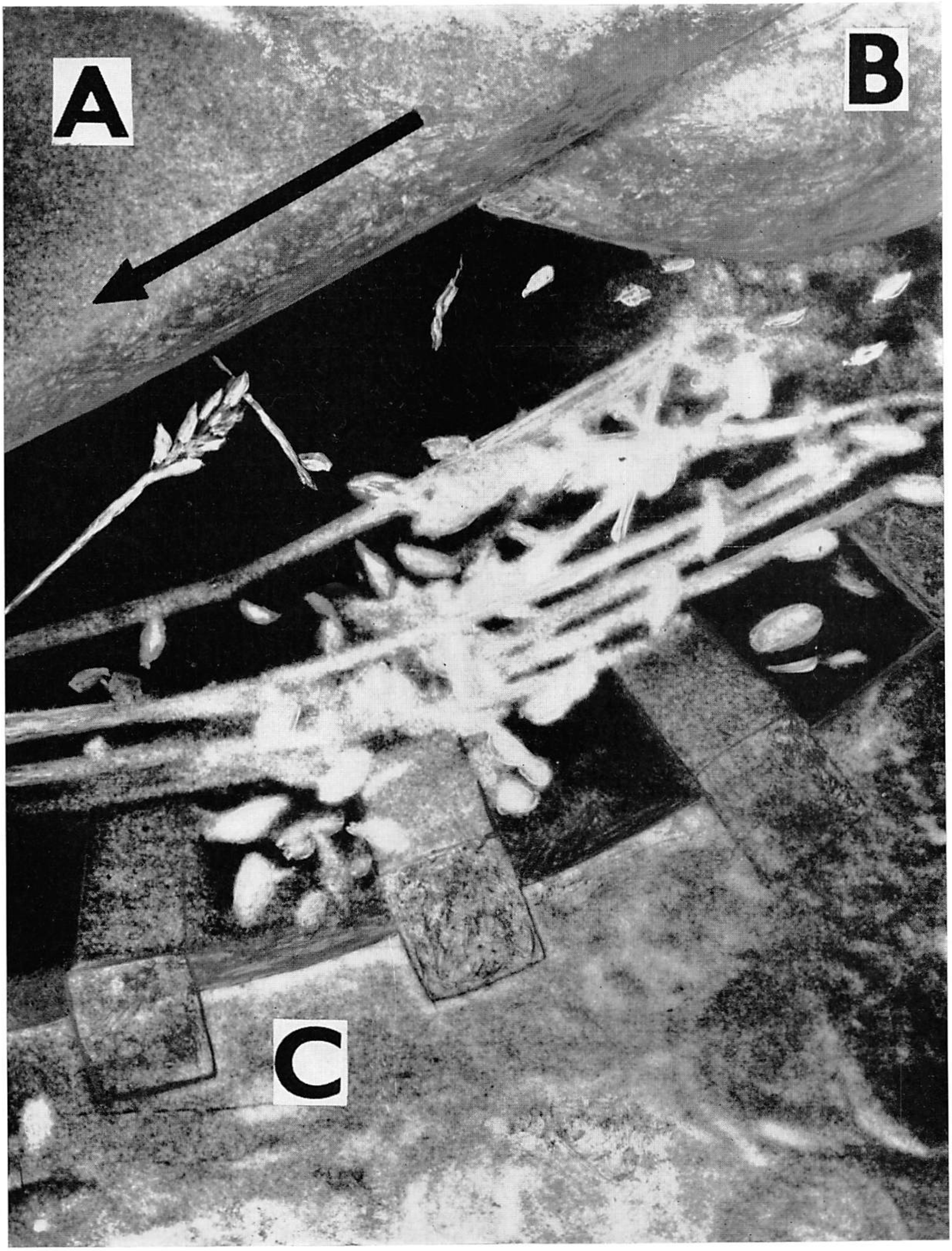


Fig. 1 : A close-up side view taken from a high-speed cine film[2] showing a threshing drum in action at a fairly high straw throughput. A—Drum, B—Beater bar, C—Concave.

that separation at the concave is reduced. In the case of crops which are difficult to thresh, timothy and other small seeds for example, the extra threshing that the partially threshed and broken heads receive, because they are unable to get away from the beaters, may be a definite advantage.

Table I

A COMPARISON BETWEEN THE PERFORMANCE OF AN OPEN AND A CLOSED CONCAVE ON CAPPELLE WHEAT*

Percentage of Broken Grain

Concave Type	*Drum Peripheral Speed ft./min.*				*Mean Concave Clearance in.*			*Moisture Content %*		*Mean*
	3,500	4,500	5,500	6,500	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	15	25	
Open	0·2	0·7	3·6	8·1	3·8	3·4	2·3	4·6	1·8	3·2
Closed	1·0	4·0	14·0	30·6	15·6	14·1	7·5	15·8	9·0	12·4

* With the exception of their concaves, the two assemblies were identical.

Alternatives to the Rasp Bar Drum

The only alternative to the rasp bar drum that has been extensively used is the peg drum. For cereals it is, in many ways, as good as the rasp bar, but it will not deal efficiently with as wide a range of other crops. The peg drum as used in American stationary threshers reduced the straw to short lengths, thus facilitating its pneumatic conveying and bulk storage. However, chopped straw is a distinct disadvantage in a combine as it complicates the task of separation.

Of the research that is being carried out here and overseas, three projects may be taken as examples of the lines of approach being followed :

1. As a less damaging alternative to the shatter principle the attempt of Stokland in Norway to employ a rubbing action on the field scale is the most interesting. The essence of the approach is a smooth, rubberised canvas drum which is rotated at slightly less than normal drum speeds against a concave of fairly conventional design which it clears by approximately ½ mm. As the crop passes through this gap it deforms the rubber of the drum and something very close to a true rubbing action is obtained against the concave. The severity of threshing can be altered by varying the pressure of air in the drum. Reports concerning its performance in the field are encouraging, but reassurance is still required about its rate of work in relation to a rasp bar drum, and its resistance to wear and to puncture.

2. The endless belt which was developed by the N.I.A.E.[3] makes use of a rubberised canvas belt carrying rubber rasp bars, which is passed over two rollers and close to an open metal concave of considerably greater than normal length. Largely due to this long concave and the vibration of the belt, its separation qualities are of a high order. To give two examples, in wheat only 2 per cent. of the total grain remained in the straw when it left the concave ; with barley the figures were a little higher, 4 to 6 per cent., but nevertheless promising. It dealt with a wide range of crops without adjustment to the concave, but output was on the low side and the rate of wear was rather high.

3. Considerable success has been achieved in Germany[4] using conical rotors in an attempt to make more use of the inherent air-moving potential of any rotating assembly such as a threshing drum. A variety of types has been tried, but they all consist, basically, of metal cones on the inside of which radial beater vanes are fitted. The cone is rotated to give the vanes approximately double normal beater bar tip speeds, and the whole then acts as a kind of centrifugal fan. The resulting air movement is utilised to suck the crop along a central delivery tube to the middle of the cone, and when it reaches the end of this tube it comes into contact with the beater vanes. These remove grain from the ears by a combination of shatter and stripping, and then all the material is conveyed away from the centre of the cone by a combination of centrifugal force and draught. The threshing efficiency of some of the rotors has been shown to be as high as that obtained with a rasp bar layout, but grain damage is, if anything, higher, and although the mechanism is simple to use, separation problems are increased and it is difficult to see how it could be fitted into the complete harvester.

The Choice of Drum for the Immediate Future

Since there is no outstandingly superior alternative to the rasp bar drum available at the moment and no prospect of one in the immediate future, a more complete exploitation of the rasp bar drum would appear to be the best policy for the present.

It is in many ways ideal for the job. It is easy to manufacture and capable of a very high rate of work. It requires little maintenance and, in contrast to many of the parts of a combine-harvester, is unaffected by hillside operation. Its limitations have been largely exposed by the very wide range of crop conditions encountered by the combine at harvest time. The damaging effect of the beaters on the grain, especially under very wet or very dry conditions, has received attention since the introduction of the combine. In addition, although its total economic effect is impossible to measure, depression of germination is serious from the points of view of the maltster and seed merchant. Straw breakage (which even if it is of no importance in itself, may aggravate cleaning problems) and both wrapping and blocking, although less of a problem as crops become cleaner and more upright, are still sources of trouble in some regions. The efficiency of the mechanism over a wide range of crops and conditions is nevertheless, impressive, but if full advantage is to be taken of it, its flexibility must be further increased. This need not imply that one design and one setting should suffice for all occasions, but that within the scope of the basic machine adjustments and extra equipment should be made available which will. There is also a real need to simplify and cheapen the combine without altering the scope of the job it does, since it is now generally admitted that " Chop threshing " and methods of that sort are not desirable alternatives for small acreages.

Improving Rasp Bar Drum Design

Threshing is always most pronounced in the early part of the concave of a rasp bar drum and, in the case of cereals and other easily-threshed crops, is frequently completed in the first few inches. At this point, the crop is moving more slowly relative to the beaters and consequently the shattering action is more pronounced than later on when it approaches beater speed more closely. In these cases the extra length of concave usually fitted is unnecessary for threshing and, in that it breaks straw, uses power and leads to more grain damage, is a disadvantage, *but* it is most important in separation (Table II). Although the grain should be removed from the path of the beaters as early as possible in order to reduce grain damage, it is clearly desirable to take advantage of the open state of the crop in the drum to achieve separation. In order to exploit this feature to the full, the aim in concave design should be to get the crop threshed as early in its passage through the drum as possible and then obtain maximum separation. This might call for a concave which could be quickly altered to suit the job in hand by adjusting bar spacing, and might entail the use of a large-diameter drum in order to increase the separating area. Such an increase in separating efficiency could lead to a valuable reduction in the size of the other straw/grain separating mechanisms. It remains to be seen whether the same end can be achieved by the multi-drum systems tried in Germany and Russia and incorporated on one current Scandinavian machine.

Table II

THE EFFECT ON SEPARATION EFFICIENCY OF CHANGING CONCAVE " WRAP " (LENGTH)

(*Wheat—Koga II*)

Concave Length—in.	6½	13	19½	26
Proportion of total grain separated—%	51·4	71·6	84·0	90·7

Neither the diameter of the drum nor the spacing of the beaters are important design features in themselves, and no reduction in impact loading on the grain can be expected to result from altering them. High peripheral speeds are advantageous in most respects, but lower speeds must be used if the drum is to produce a good quality sample under all harvesting conditions. It has been shown at the N.I.A.E. that wheat grains will withstand impacts of up to ~3,500 ft./min. on the endosperm without serious damage, but only ~1,000 ft./min. on the embryo. Barley and many other crops will withstand higher speeds, but few will withstand at all moisture levels direct impacts of the magnitude which must result if the shatter principle is to be put into effect and a smooth flow of material through the drum maintained. This does not mean that all grains threshed out using this principle are damaged, or that present damage levels cannot be reduced. In the first place only a fraction of the grains receive a direct impact, and, in the second, if other aspects of drum design and crop presentation receive attention, it should be possible to effect a general lowering of drum speeds sufficient to reduce the incidence of damage to levels which are of no consequence in nearly all cases.

Operating the Drum to Best Advantage

With any design, drum speed can be kept to a minimum only if the crop is in the right condition and is presented to it in the correct way. Assuming it to be fully ripe, its threshability and susceptibility to damage are closely related to its moisture content. Cereals thresh more easily as they dry out, but because they are progressively more prone to breakage as their moisture level falls, it nearly always pays to thresh them when not *too* dry, but on the other hand not wet enough to bruise. The grain damage problems with combine-harvesters have arisen largely because so much grain has to be harvested outside the optimum moisture range for threshing. If in cereals combining could be restricted to occasions when the grain moisture was between 16 and 20 per cent. these difficulties would rarely be encountered.[5]

Presenting the crop to the drum in an orderly, heads first stream leads to greater threshing efficiency, and enables lower drum speeds to be used. This is logical, in that if the initial work in accelerating the crop is done on the heads, these are shattered earlier and more effectively than later when the crop as a whole is travelling faster. The drum is very tolerant of different feed rates, but should always be kept full to avoid the increase in grain damage which results if it is so low that continuity of the stream is lost.

The precise concave clearance used is less important than drum speed, both for threshing efficiency and grain damage (Tables I and III). This also follows from remarks above concerning the rôle of the concave. It is, however, important to avoid extremes. Excessively wide clearances do not give smooth flow and gentle threshing, often quite the reverse, as the passage of the crop is slowed down and separation efficiency reduced considerably, while the amount of shatter caused by the beaters is not altered.

Table III
THE EFFECT OF CONCAVE CLEARANCE ON THRESHING EFFICIENCY

Total Grain Threshed—%				
Mean Concave Clearance in.	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$
Wheat (Koga II)	99·9	99·9	99·7	99·5
Barley (Proctor)	97·0	95·2	94·4	—

Cutting Table Components

In view of what has been stated above about the optimum method of presenting the crop to the drum (heads first), the obvious question is, does the cutting table do this ? With the exception of those straight-through machines which are equipped with a canvas-feed elevator, it does not. Here, therefore, may be an opportunity for designers to improve efficiency of threshing, but such a change is by no means straightforward on a typical self-propelled machine, because the auger is usually fitted close to the cutter bar, and works well in this position, particularly in laid crops. In this position the auger can very quickly get hold of the butts and pull them in ; in difficult conditions this is a distinct advantage over a canvas feed, but it does mean that the drum usually receives the crop butts first. A major change would therefore be necessary to achieve a heads-first feed because it would rarely be satisfactory simply to increase the distance between the cutter bar and the auger with this end in mind.

Not only does the direction of crop feed have an influence on drum performance, but so has the smoothness of flow, particularly at high throughputs. Under steady flow conditions the drum assembly threshes and separates better, and the straw shaker works more efficiently. Crop condition is of course an important factor in smooth flow, but it is not always realised how easily any one of the cutting-table components (the dividers, the reel, the cutter bar, the auger or the vertical feed conveyor) can create uneven flow by causing the crop to " hang-fire " momentarily.

In this connection it is surprising that it is not always easy to give precise instructions for reel speed setting, even for standing crops, and there is in fact some disagreement between manufacturers' instruction books on this point. In such a discussion, reel speed is best described as a ratio :

$$R = \frac{\text{Peripheral speed of reel (ft./min.)}}{\text{Forward speed of combine (ft./min.)}}$$

When R = 1 the reel hardly touches the ears in a standing crop. On the other hand, every operator is familiar with the grain losses which result[6] if R is increased too much, to say 1·7 or more. Some increase may be essential under laid crop conditions, and in this case slight losses at the reel are a small price to pay for getting the crop cleanly on to the table. At one time recommendations were that reel position and speed ($R < 1$) should be such that the crop was caused to lean away from the knife and thus feed cleanly, butts first. This recommendation is less common now, but it is certainly wrong to go to the other extreme and pull the crop back over the top of the auger, because the auger then whips it forwards and down again, causing grain losses and uneven flow in the process.

In certain combines, reel speed has been linked to forward speed, but this was not very satisfactory because just when a higher reel speed was required for picking up a laid patch the combine usually had to slow down. Perhaps the ideal is for reel speed to be linked to forward speed, but with the driver having control over the ratio. A largely satisfactory alternative, however, is to provide the driver with a straightforward reel-speed control.

The plain reel is now almost a thing of the past. There are of course conditions where the pick-up reel is essential, but how is it that it is now used as a universal reel when not long ago a plain reel was substituted for work in standing crops ? Several factors have contributed—firstly a cleaner design of pick-up reel, secondly more skill in setting, and thirdly reel-setting controls which enable the driver to move the reel out of the way when it is about to cause trouble.

Little need be said about the cutter bar ; because of the vibration which it causes it has been much criticised, but there seems little prospect of an alternative at a competitive price. Initially, binder practice was followed with a knife register of two fingers, but more and more combines now use a one, or just-over-one-finger register, with apparently an improvement in performance. It is sometimes possible for the forward speed of a combine to be limited by the fact that the knife is beginning to tear or pull the stubble. With existing designs higher knife speeds are hardly to be recommended because of vibration ; if tearing of the stubble occurs often, and grain losses are small, it usually means that if a 10-ft. machine is involved it *should* have been fitted with a 12-ft. cutting table.

The Drum/Straw Shaker Relationship

If the threshing losses which a combine is causing are measured as its forward speed is gradually increased up to a point where these losses become excessive (termed " rating " in an N.I.A.E. test[7]), a curve of the form shown in Fig. 2 is usually obtained. When it is the straw shaker losses which become excessive in such a test, as is common, the question is, is the straw shaker being overloaded or is the situation that sufficient grain is not getting through the concave in the way that it normally does ? To quote percentages, if a concave is working well ~75 per cent of the grain going through that machine passes *through* the concave and straight to the pan and sieves, so that only 25 per cent. of the grain is left in the straw for the shaker to separate out. Some work in California[6] indicates what can happen when the mechanism is over-loaded (indicated by excessive losses), the losses occur because the concave is no longer doing the separating and perhaps 50 per cent. of the total grain is passing on to the straw shaker. The straw shaker is therefore not entirely to blame, it is the concave which is largely at fault. This observation has a bearing on the alternatives to the conventional drum which has been mentioned earlier—the Endless Belt Thresher,[3] and the multi-drum machines. The object in these cases was to get such efficient separation that this rather clumsy mechanism, the straw shaker, could be eliminated or reduced in area, thus making the combine a more compact machine.

The argument " narrow drum *versus* wide drum " has been going on for a very long time and has not yet been completely settled. On the market there are examples of both extremes which, from the points of view of their owners, are doing very good jobs. However, it seems more than likely that between the two extremes there lies an optimum, and it would be an advantage if this optimum could be found so that the design of this and its associated mechanisms could be stabilised. A wide drum can satisfactorily feed a wide straw rack (a one-piece straw shaker) because the latter only works effectively when it has a very shallow layer of straw on it. There is no record of a set of straw walkers in a self-propelled combine being replaced by a straw rack. If this were done, separation would probably be reduced because of the relatively thick layer of straw normal in self-propelled machines. A system of three to six walkers is effective, however ; this mechanism is asked not only to move the material rearwards, but also to tease it out. Where the planes of the walker motions intersect, teasing takes place, but as soon as the movement of the straw becomes rhythmic and regular the mechanism is then acting as a conveyor and less as a separator. This (and the Law of Diminishing Returns) means that increases in the length of straw walkers do not give as spectacular results as one might expect. What is needed for further separation is a change in the plane of action to break up the mass ; this is clearly the aim with stepped walkers. A possible alternative approach would be to have two sets of very short walkers between which would be arranged a " teasing drum."

Optimum Number of Straw Walkers

No work on the optimum number of walkers has been published. Numbers in common use range from three to six. If, for the sake of discussing the extreme, the case of a shaker consisting of 10 or 12 units is considered, the mass will probably be moved in such small steps that no appreciable separation occurs and once again the mechanism is acting only as a conveyor. However, within the normal range (three to six) differences in efficiency are probably small.

Trailed *versus* Self-Propelled Combines

Choosing between trailed and self-propelled combines is to a large extent a question of economics, plus, regrettably, the " status symbol " aspect of the latter type. The trailed machine appears to be receiving less attention than it deserves (1961 production for home market 88 per cent. self-propelled machines), particularly since modern tractor design has successfully eliminated several of the major snags previously associated with such an outfit.

Sieves and Their Relationship With the Other Components

Current practice is to fit an adjustable sieve in the upper position in the shaker shoe. In certain cases, however, fixed hole sieves have been used in this position and, although these may sometimes be successful, the fine adjustment obtainable with the former type can be very useful—*e.g.*, when brittle straw (" Cappelle " wheat), and the " spearing " which it gives rise to, is encountered.

The characteristics of cereal grains (again " Cappelle " is brittle) are fairly well known to plant breeders, but it is worth enquiring whether they take sufficient note of straw brittleness and other threshing characteristics. It should be added that their success in producing short-strawed varieties has been welcomed by combine users ; combine-harvester efficiency will always be greater with varieties which stand up under all conditions.

Attempts have been made both in America and on the Continent to replace the straw shaker and sieves of a combine by a single mechanism. One alternative is a device like a cyclone into which the mixture is fed together with a high-speed air stream. The straw and chaff are intended to come out of the top and the grain out of the bottom. It can only be assumed that this idea has not met with much success as it does not appear to have been pursued. The process known as " Chop-threshing " gained limited acceptance on the Continent, but for a number of reasons, including the design of our buildings and our labour position, is unlikely to find favour here. The ability of the flail-type forage harvester to rescue at least a part of very badly flattened crops has been reported in the press. The subsequent separation of the grain from the chopped mass cannot be carried out very rapidly and, although the amount of grain damage done by the harvester was not too large, it was above average ; for these two reasons therefore the method seems unlikely to find any general application. In this case the secondary function of the concave (separation) is absent and the load on the remainder of the mechanism is correspondingly increased.

Elevators and Secondary Cleaning

The reliability of combine-harvester elevators has improved appreciably over the past five or ten years, and during the same period, thanks to the extensive use of herbicides, they have had progressively less green material to handle. It is unforgivable that an elevator should be the bottle-neck in a combine (it is normal for the drum or straw shaker to be the limiting factor). Therefore most manufacturers have wisely over-designed their elevators so that they can handle everything the combine is ever likely to produce.

A secondary cleaning mechanism (usually a rotary screen) is comparatively rarely seen on new tanker combines in this country, and this type is in the majority. Because their use requires time for sacking off the weed seeds and in some cases the small grain, they are not generally favoured. It is logical to argue that " no cleaner is better than a poor one " and that this mechanism should never be allowed to form a bottleneck. There is no reason why efficient cleaners should not be designed and the sacking-off problem avoided ; by their use it is possible to reduce the number of weed seeds that are returned to the soil.[8] However, the use of herbicides has reduced the proportions of the weed-seed problem. Compared with a grain cleaner installed in the barn, the secondary cleaner on a combine is at a disadvantage. It is much easier to clean grain at the barn because, in the course of the relatively short time between harvesting and cleaning, the grain will usually absorb some of the moisture from the greenstuff and the weed seeds. Thus the aerodynamic characteristics of the rubbish change and it is then easier to blow out. In many cases it is therefore wrong to make big efforts to get a saleable sample straight off the combine. It is preferable to get *all* the grain off the field and clean it afterwards, rather than put extra blast on the combine sieve and lose some of the grain over the back.

If an artist draws a futuristic combine he always adds a drier for good measure—is this sensible ? The difficulty here is that if say 5 per cent. of moisture has to be removed from wheat, it cannot be done at a very high rate, if damage, even of milling wheat, is to be avoided. With the temperature limits at present accepted as safe it will have to remain in the drier for a minimum of about 40 minutes, and this means that if the combine is handling 6 tons an hour the drier and tank must have a capacity of 5 to 6 tons—a cumbersome machine indeed. To remove 1 or 2 per cent. of moisture might be possible, but for the 4, 5 or 6 per cent. which are quite common in this country it would seem to be impracticable.

Power Requirement

The majority of combines appear to be fitted with engines which are more powerful than is required for normal conditions, even on slopes.[9] To some extent the provision of this surplus power can be explained by the need for momentum to carry the drum through the type of partial blockage which occurs when a wad of material passes through it. Theoretically, however, a smaller engine fitted with a large flywheel would achieve the same result. Fifty per cent. or more of the power used goes to the drum,[10] and it may be that when the instantaneous power required by this component has been examined it may be possible to try reduced engine powers.

However, horse-power is relatively cheap nowadays and, in relation to labour costs, is likely to get cheaper.

Flotation and Traction

In difficult harvests like 1960, and in many cases overseas, it is vital that a combine be provided with sufficient contact area with the ground to prevent it sinking in. It would be uneconomic to fit all combines with such large tyres that they could deal with all conditions. It is logical, however, to fit a smaller tyre as standard and leave room for a change where it is necessary. It is our personal view that a simpler way of tackling this problem, and this would have been appreciated in 1960, would be to allow in the combine's design for the fitting of simple cage wheels on the outside of the combine's wheels. This would provide adequate flotation and, where necessary, traction.

The Controls

The present trend is towards reduction of effort and the provision of remote controls for as many adjustments as is economically possible. No matter how many remote controls are provided, some operators will ask for yet another. There is the danger that manufacturers may get involved in a race to provide the maximum number of " knobs "—surely not a desirable objective. Every additional control of this type adds to the cost and complexity of the machine. However, there are several controls, such as remote or rapid control of drum speed, which are, in our view, not luxuries, but economically sound developments. Incidentally, it follows from what has been said earlier about drum settings that if, for economic reasons, a choice must be made between rapid adjustment of drum speed or of concave clearance, the former is preferable.

Automation

With reference to automation the combine is at a major disadvantage. Some of the aspects of performance upon which combine settings, such as forward speed, must be based, are difficult or impossible to measure or " sense " electrically. Theoretically forward speed could, in an automated machine, be varied according to the losses coming over the back *if* there were in existence a " magic box " which could be attached to a combine to provide such a signal. There seems no prospect in the forseeable future of such a device being available.

In Russia attempts have been made at linking forward speed with the torque requirement of the drum. Thus when drum speed is pulled down slightly by a heavy patch in the crop, forward travel of the machine is reduced accordingly. Such a device might have some advantages, but at present this operation is one of the less difficult tasks of the driver. In addition one can imagine that in the main wheat-growing areas of Russia rapid changes in crop condition would be encountered less frequently than in the United Kingdom.

The Operator and His Environment

The fact that noise and vibration are contributing factors to operator fatigue is now more generally recognised, and where long working days are involved this can be important and has a bearing on engine position.

In the future an air-conditioned cab or cowl will not be regarded as a luxury—however the need for one can be substantially reduced by suitable placing of the operator's platform.

At least in this country, combine forward speed is not likely to increase substantially, at least whilst a human driver is in charge. Speeds of 5 to 6 m.p.h. may be possible for other operations, but the driver's reaction time sets a limit on the combine. He must be able to see an obstruction or a laid patch of corn, operate the control and have the appropriate component (cutting table, reel height) reset before the point is reached. For efficient operation the driver should be given as much opportunity as possible of seeing what his combine is doing. It needs a second man to see what the combine is losing, but it is relatively easy to let the driver see the quantity of tailings flow and to enable him to check the amount of rubbish or broken grains in his sample so that he can do something about it. The second man on a bagging machine was always available to keep an eye on such points as these, thus his absence from a tanker may affect operation adversely.

Instructions for combine-harvester operators have been treated at length elsewhere, but to conclude it is worth listing four rules which are often not observed, and which can be fairly generally applied :

1. Start a field with *known* settings (usually those in the instruction book).
2. Alter settings one at a time, and only after observing performance.
3. A rule which is somewhat paradoxical : Accept a drum setting that leaves an occasional grain in the ears—this is the nearest practical approach to the optimum setting.
4. Also paradoxically : Accept a slightly dirty sample. It may be necessary to do this to keep losses to a minimum, and in any case cleaning is easier and more effective in the barn.

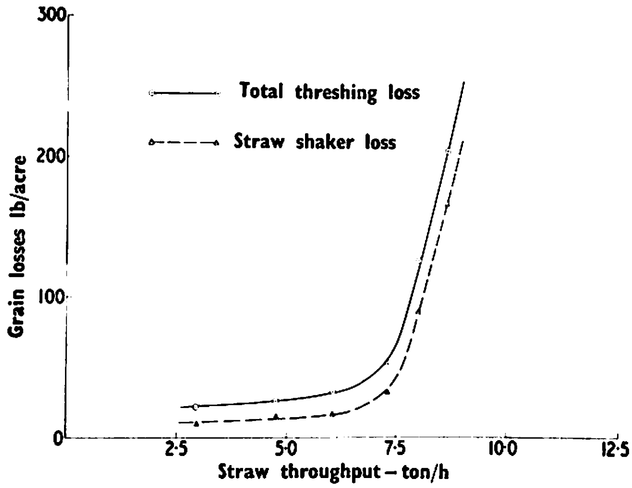


FIG. 2 : Curves showing a typical relationship between straw throughput and grain losses in wheat. The difference between total threshing loss and shaker loss is made up of sieve and drum losses. The shaker losses increased sharply when a certain throughput was exceeded, whereas the other losses did not.

REFERENCES

[1] CHURCH, L. : " Partial History of the Development of Grain Threshing Implements and Machines." *U.S.D.A. Agric. Res. Admin., Bur. Plant Ind., Soils and Agric. Engng.*, Sept., 1949. Inf. Series, No. 73.

[2] SCHULZE, K. H., *et al.* : " Cinematographic Investigation of the Threshing Process in a Beater Bar Drum." *Grundl. der Landt.*, 1957. Heft 7, 113.

[3] CHALMERS, G. R., NATION, H. J., RAYBOULD, F. W. : " Some Experiments With an Endless Band Threshing Mechanism." Case Study 19, *Nat. Inst. Agric. Engng., Silsoe*, 1952.

[4] WESSEL, J. : " The Threshing Process Within a Conical Rotor." *Landtech.Forsch.*, 1960, 10(5), 122–130.

[5] ARNOLD, R. E. : " The Effect of Harvest Damage on the Germination of Barley." *J.Agric.Engng.Res.*, 1958, 4(1), 24.

[6] GOSS, J. R., *et al.* : " Performance Characteristics of the Grain Combine in Barley." *J. A.S.A.E. (Mich.)*, 1958, 39(11), 697.

[7] HEBBLETHWAITE, P., HEPHERD, R. Q. : " A Detailed Test Procedure for Combine-Harvesters." *Ann. Rep.*, 1960–61, *Nat. Inst. Agric. Engng., Silsoe*, 1962.

[8] PETZOLD, K. : " Combine-Harvesting and Weeds." (Transl.) *J.Agric.Engng.Res.*, 1956, 1(2), 178.

[9] " Ransome's ' 902 ' Self-Propelled Combine-Harvester." *Test Rep.* 304, *Nat. Inst. Agric. Engng.*, 1962.

[10] BURROUGHS, D. E. : " Power Requirements of Combine Drives." *J. A.S.A.E. (Mich.)*, 1954, 35(1), 15.

DISCUSSION

MR. WYNN opened the discussion by saying how interested everyone had been in the paper. He asked for more information concerning the advantages of closed concaves.

MR. ARNOLD pointed out that the results quoted in the paper were obtained from a single trial, but that he would expect them to be typical for cereals. More damage occurred when closed concaves were used because the grain could not get out of the way of the beaters sufficiently quickly after threshing. He had had no experience with small seeds, but where the crop was difficult to thresh he thought that closed concaves could thresh more efficiently.

Mr. Arnold was then asked if there was a danger, with wide drums, of fatigue failure of the drum shaft.

Mr. Arnold said that there was little risk of this. A radial load applied to a beater bar is generally distributed along the length of the shaft, and torsionally all drum shafts had a very high safety factor.

The question of whether the advantages of heads first feeding could be repeated was then raised.

Mr. Arnold said that the advantage lay in the difference between the speed of the crop and that of the beaters at the point where the crop first meets the beaters. In heads first feeding the initial work of the beater bars was done on the ears of the crop. Consequently threshing took place earlier, and was more pronounced than if it took place later when the crop had been accelerated by beater action on some other part of it, and thus the speed of the ears was nearer to that of the beaters.

Mr. Wynn asked if the shape of beater bars was important.

Mr. Arnold said he had no experience of trying different types, but quoted the results of an experiment which had been carried out in Germany. This had shown that streamlining the bars and thereby reducing the amount of windage in the drum was a disadvantage in that separation at the concave was reduced. He added that the ribs that were to be found on most bars enabled the drum to get a grip on the crop. He thought more use should be made of the draught created by the drum in separation and, perhaps, in the first stages of cleaning.

Why did the ribs on beater bars alternate in direction it was asked.

Mr. Arnold said that if they did not, the crop would tend to work its way to one side of the drum.

MR. HEBBLETHWAITE added that having the ribs all one way would put an undesirable side load on drum bearings.

The next questioner asked if a change in the distance between the cutter bar and the cutting table auger could be expected in the near future.

Mr. Hebblethwaite said that he did not envisage any change, at least for the British market—the auger would remain fairly close to the cutter bar so that the former could pull in a laid crop without the material hanging about just behind the cutter bar. However, if in the future heads first feeding is adopted, the auger's position might have to be changed.

Mr. Hebblethwaite was then asked to explain why he had said that a secondary cleaner used on a tanker could, if necessary, prevent some weed seeds being put back on the field. Surely, even at present the weed seeds were collected in the tank. Or did the speaker envisage a new position for the cleaner between the top and bottom sieves ?

Mr. Hebblethwaite said that he was supplementing his observation that operators tried hard to get a saleable sample straight off the combine, and this was achieved by *blowing* out weed seeds if a cleaner is not fitted.

An explanation was sought as to how concave clearance had been measured in the experimental work quoted, and what the virtues were of the various types of clearance.

Mr. Arnold said that all measurements had been the average distance between drum and concave, and that most of the work had been carried out with a setting that was $\frac{1}{8}$ in. wider at the inlet than at the outlet. He went on to say that work had been carried out in which the inlet : outlet clearance ratio had been varied from 3 : 1 to 1 : 3 and the average clearance varied at the same time. Very briefly this had shown that both feeding and clearing problems were increased if the clearance was too wide at the inlet to the drum. If too narrow, grain damage increased and, although threshing efficiency was slightly improved, the best compromise was a taper of from $\frac{1}{8}$ to $\frac{1}{4}$ in.

Asked if large diameter drums required more or less power than small ones, Mr. Arnold replied that, providing everything else remained the same, drum diameter had very little effect on power requirement.

In reply to the next question, which was whether a heavy drum was an advantage, he replied that it was essential to have a reserve of momentum in the system and that if the drum itself were light a flywheel and/or a heavy engine could provide momentum.

The speaker's views were then sought on the location of the engine ; placing the engine in an accessible dust-free position on top of the combine is a useful step forward, although it does reduce stability. In spite of this, the newly-introduced Viking combine had its engine inaccessibly placed (underneath). Saddle tanks help to bring down the centre of gravity, but engines were still being put underneath. Were there any other advantages for low placing ?

Mr. Hebblethwaite agreed that it was largely a question of choosing between stability and accessibility. Where steep slopes are common a low placing is obviously better. Other factors governing engine location are noise, vibration, fumes and structural strength—and therefore engine position will always be a compromise.

The opinion was then expressed that concave clearance was more important than had been indicated in the paper ; it was suggested that one could only go so far in reducing drum speed and then, if straw breakage and grain loss were still occurring, the concave clearance had to be increased. In addition, the importance of concave clearance in relation to straw breakage had been underrated.

Mr. Arnold said that, over the range of concave clearances commonly used in the field, the trials he had carried out suggested that no material effect on either grain damage or straw breakage would be likely to result.

Mr. Hebblethwaite said that he did not agree fully with Mr. Arnold on this point and would, like the questioner, open the concave as far as possible to avoid "over-chaffing." He thought that drum power consumption would go up fairly rapidly as close settings were approached and this would indicate that straw was being "ground" through the final $\frac{1}{8}$-in. clearance. The general picture was "Put more emphasis on selecting drum speed" *not* "Forget clearance altogether."

A further questioner said that he felt that operator and farmer education was as important as good design. He mentioned Mr. Hebblethwaite's reference to leaving behind an occasional grain in the ears, and added that many farmers sprayed their corn too late with the result that some of the crop, say 10 per cent., did not come ripe with the remainder of the field. To get this unripe grain out of the ears required what amounted to excessive threshing for the remainder of the crop. Variation in soil type within a field had the same effect. Had the speakers any ideas for overcoming these problems ?

Mr. Hebblethwaite re-phrased this question as : " How can an operator alter the setting of his machine to deal with patchiness ? " and added that unevenly distributed fertiliser could produce the same effect—*e.g.*, unripe strips at perhaps 10-yd. intervals across the field.

Even with remote control of drum speed the operator could not hope to deal with all such variation, although he could alter his settings if one side of the field were different (in soil type) from the other. There is no complete answer to the problem from the point of view of combine design—education of operators (of sprayers and distributors) could stop the trouble arising. There is no immediate hope of automation—a device at the rear of the machine to " sense " unthreshed heads and to increase drum speed accordingly is unlikely to be developed.

MR. G. L. REYNOLDS asked if any work had been done on the optimum setting of the wind deflector or, in other words, what was the best angle for the airstream to strike the sieves. In his experience this could sometimes be very critical.

Mr. Hebblethwaite commented that this was a difficult question and to his knowledge it had not been the subject of research, at least in the context of combines. It would be difficult to investigate because of its dependence on crop condition. It was relevant to mention that because separation in the airstream is an effect which relies partly on gravity, scaling down a combine design, to produce a low machine, can give rise to difficulties. If the airstream is too near the horizontal, the sieve becomes very difficult to set—a small change in one direction and the sample becomes dirty, a change in the other and all the grain is blown over the back.

MR. LEWIS FOX proposed a vote of thanks, saying how effectively the speakers had managed to explain their work in words of one syllable.

INSTITUTION NOTES CONTINUED

Institution Examinations

THE 1962 Examinations were held in July at the Essex Institute of Agriculture and at Rycotewood College, Oxfordshire. The results are given on page 105. Two candidates for the N.D.Agr.E. were awarded Second Class Honours, and Distinction was gained by two entrants for the Membership Examination.

Donation by the Founder President

The Council at its meeting on August 16th received with gratitude and appreciation a donation of £1,000 by the Founder President, Lt.-Col. Philip Johnson. This munificent addition to the Institution's funds comes at a very appropriate time, the Council at present having under review the necessity to build up a reserve fund and income which will allow an expansion of activities.

Colonel Johnson's gift follows another of £100 which he donated several years ago.

Library Service

Members are reminded that it is possible for them to obtain almost any book or publication dealing with the various aspects of agricultural engineering on application to the Secretary.

Books may normally be retained for two weeks, or longer by arrangement.

Membership Certificates

Some hundreds of certificates have now been issued.

Copies may be obtained on request—unframed at no charge to members ; framed at 15/-, post free.

Private Medical Treatment

In response to requests received from a number of members, arrangements have been made for the formation of an Institution Group with the object of providing private treatment for members and their families at 20% less than the standard rate of subscription.

Particulars will be found on the slip enclosed, and members interested are asked to write direct to the Group Secretary at the address indicated and not to the Secretary of the Institution.

Institution Tie

Sufficient members being interested in the provision of an Institution Tie, a design has now been approved by the Council and supplies will shortly be available. Order forms may be had on request from the Secretary.

The design has been based upon that used for the Presidential Badge, with a dark-green or blue background to choice.

Income Tax Rebate

Those members who have not already made the necessary arrangements are reminded that their subscriptions are allowable as an expense for income tax purposes. Application for the necessary form (P.358) should be made to the local Tax Inspector.

Journal Binders

Binders to accommodate 12 Journals may be had on application to the Secretary, price 10/6, post free.

INSTITUTION EXAMINATIONS

The Examination for the National Diploma in Agricultural Engineering was held at the Essex Institute of Agriculture, and the Membership Examination at the Essex Institute and at Rycotewood College, Oxfordshire, by kind permission of the respective Principals, Mr. B. H. Harvey, B.Sc., N.D.A., N.D.D., and Mr. C. A. Goodger, C.I.Agr.E.

NATIONAL DIPLOMA IN AGRICULTURAL ENGINEERING

Second Class Honours	*Centre of Training*
† GIBSON, J. J. B., Bury St. Edmunds, Suffolk	Essex Institute of Agriculture.
WHITTAKER, H. V., Frome, Somerset	West of Scotland Agricultural College.
Pass	
BANKS, R. J., Cambridge	Essex Institute of Agriculture.
BARBER, A. D., Warrington, Lancs.	Essex Institute of Agriculture.
‡ DAVIES, J. E., Alcester, Warwicks.	West of Scotland Agricultural College.
‡ DAVIES, R. W. R., Lydney, Glos.	West of Scotland Agricultural College.
‡ EVANS, D. V., Monmouth	West of Scotland Agricultural College.
† GEDYE, I. D., Birmingham	Essex Institute of Agriculture.
HAYWOOD, E. J., Royston, Herts.	Essex Institute of Agriculture.
** KEESE, P. H., Kenya	West of Scotland Agricultural College.
LAIRD, T. R., Stirlingshire	West of Scotland Agricultural College.
* LANDERS, J. N., Liverpool	Essex Institute of Agriculture.
MCLAREN, E. A., Kilmarnock	Essex Institute of Agriculture.
MCNAB, N. B., Glasgow	West of Scotland Agricultural College.
NORRIS, R. J., Thorpe Bay, Essex	Essex Institute of Agriculture.
SHARRATT, B. E., Dalton, Northumberland	King's College, University of Durham.
‡ SUTHERLAND, P. R., Crickhowell, Breconshire	West of Scotland Agricultural College.
WALKER, A. E. L., Glasgow	West of Scotland Agricultural College.

The Panel of Examiners were agreed that the standard of entries to the examination was maintained. There was no candidate of sufficient merit for the award of the Johnson Medal, last presented in 1958.

* Winner of 1961–62 " Dunlop " Scholarship.
† Winner of 1961–62 Shell-Mex & B.P. Bursary Award.
‡ Intermediate N.D.Agr.E. gained at N.W. Wiltshire Area College of Further Education.
** Intermediate N.D.Agr.E. gained at College of Aeronautical and Automobile Engineering.

GRADUATE MEMBERSHIP EXAMINATION

Pass with Distinction	*Centre of Training*
LAING, A. S., Pontefract, Yorks.	Private Study.
WISE, B. W. F., Salisbury, Wilts.	Lackham School of Agriculture.
Pass	
AKINYEDE, P. A., Nigeria	Lackham School of Agriculture and College of Aeronautical and Automobile Engineering.
BARTON, P. S., Grantham, Lincs.	Private Study.
BAIRD, G. J., Comrie, Perthshire	Private Study.
BOWMAN, A. M., Alexandria, Dunbartonshire	West of Scotland Agricultural College.
BROWN, A. J., Peterborough, Northants.	College of Aeronautical and Automobile Engineering.
KANE, D. F., Andover, Hants.	Rycotewood College.
KNIGHT, D. W., Moreton Morrell, Warwicks.	Private Study.
LARTEY, P. A., Ghana	College of Aeronautical and Automobile Engineering.
LAVY, M., Nyasaland	Lackham School of Agriculture.
LEMON, R. E., Arnside, Westmorland	College of Aeronautical and Automobile Engineering.
LUCAS, G. S., Shipston-on-Stour, Warwicks.	Rycotewood College.
LUCKSFORD, R. J. L., Swindon, Wilts.	Lackham School of Agriculture.
ROWELL, M. H., Chelmsford, Essex	Private Study.
SAVAGE, R., Bristol	Lackham School of Agriculture.
SENIOR, G. D., Westcliff-on-Sea, Essex	College of Aeronautical and Automobile Engineering.
SKINNS, D. A., Woodhall Spa, Lincs.	Rycotewood College.
THORBURN, M. E. G., Southern Rhodesia	College of Aeronautical and Automobile Engineering.
TYBLEWSKI, J., Shire Hall, Shrewsbury	Private Study.
WATKINS, C., Melksham, Wilts.	Lackham School of Agriculture.
WEBB, B. W., Bristol	Lackham School of Agriculture.
WHITTALL, R. W., Southern Rhodesia	College of Aeronautical and Automobile Engineering.

The Examiners were pleased to recommend that Distinctions be awarded to two candidates. These are the second and third Distinctions to be awarded in the course of the five years in which the examination has been held.

CULTIVATION AND CROP PROCESSING TOOLS FOR LESS DEVELOPED AREAS

A summarised Report of a Paper presented to the West Midlands Branch of the Institution on 27th November, 1961, by N. M. GARRARD*

WHILE mechanised methods of cultivation offer considerable possibilities of increasing the production of food in the less-developed countries, work with equipment designed for use in totally different conditions has often had disappointing results. Lack of knowledge of basic climatic and other environmental factors has resulted, for example, in insufficient attention being paid to the paramount need in dry areas for conserving moisture. The use of mouldboard ploughs has in some cases greatly increased loss of moisture from the soil, and has in fact reduced crop yields, compared with those obtained by primitive traditional methods. In other cases mechanised irrigation methods and a consequently increased rate of pumping have resulted in using up water supplies more quickly than they are available, with almost disastrous results. Where bad results of this kind have been obtained it has proved very difficult subsequently to persuade the local farmers to try further mechanical methods.

In addition, sudden mechanisation on an extensive scale could result in widespread unemployment in the many areas where up to 80 per cent. of the population is at present employed in rural work. A gradual approach to mechanisation and the introduction of agricultural machinery is therefore required, allied to development and improvement of existing local methods and equipment, and these must be supplemented by a programme of education.

Limiting Factors

If peasant farmers are to be helped to increase their crop yields, and if their burden is to be lightened, it is necessary to pay attention to a variety of technical, physical, political and sociological factors. These include traditional methods of cultivation, types of crops suited to the area, size of holdings, land conditions, land tenure, moisture conservation, irrigation possibilities, size of family a holding must support, farm income, marketing facilities, possibilities of co-operation and alternative employment for persons displaced by the mechanisation of farming.

In parts of Africa, holdings range from 3–15 acres, families are large, and grazing has to be provided for work animals. It has been estimated nevertheless that a substantial number of African farmers could afford to invest up to £120 in purchases of machinery. This figure must be considered, however, in relation to the fact that machinery and equipment delivered to the middle of Africa may cost nearly double its price in the country of origin.

Pattern of Development

It is suggested that making a study of local implements and then improving them offers a more practicable method than the immediate introduction of tractors and other expensive machines—if the transition from the use of primitive tools to mechanised farming is to be made successfully.

The National Institute of Agricultural Engineering has therefore carried out a certain amount of work on animal-drawn cultivation tools, ox carts and rice-threshing equipment. The basic cultivation tool which has been developed consists of a two-wheeled chassis and toolbar, on which can be mounted a plough, ridger, seeder, tines, etc. When not required for use with these implements the chassis can be fitted with a transport body. The farmer is thus provided with a cheap universal tool, and with its use he can gradually learn the importance of individual tools for each agricultural operation. In this way he will eventually be ready for partial mechanisation.

A particular virtue of this multi-purpose tool is that crops are sown in rows. The subsequent inter-row cultivations eliminate the hand labour at present required for hand-weeding broadcast crops. The next stage of development is to fit a prime-mover to the chassis, such that it can also be used to drive an irrigation pump or crop-processing machine.

**Commonwealth Liaison Officer, National Institute of Agricultural Engineering.*

The N.I.A.E. has also been concerned in the development of a small portable paddy thresher, with a capacity of up to 1,500 lb. of threshed paddy per hour, and work is proceeding on the design of a small drier for rice.

Manufacturers in France, Germany and Japan are similarly alive to the potentialities of the market in the less-developed countries, and have been surveying the requirements of peasant farmers in Asia, the Middle East and Africa. By improving small tools now it is hoped to establish a firm market in the future for mechanised equipment.

Contract Services

Contract machinery services can play a valuable part, though government-sponsored schemes have failed, in many cases, to survive more than two or three seasons. The reasons for such failures include lack of adequate roads or tracks, poorly-trained staff, lack of suitable administrative provisions, bad public relations and political interference. To be successful, good public relations, supervision and service maintenance are essential, together with a programme to educate farmers to adopt suitable methods of farming and to make any necessary social readjustments.

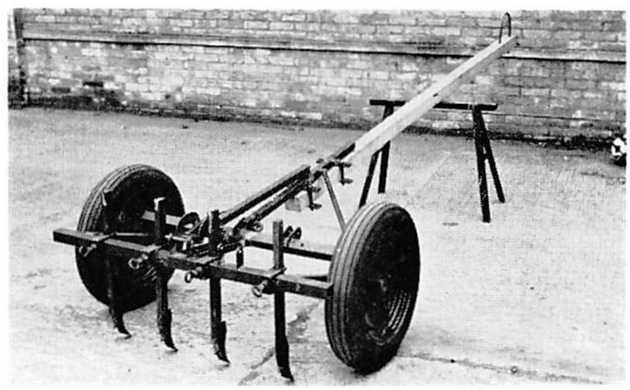
Recommendations

Positive steps to achieve the mechanisation of farming in the less-developed areas should thus be based on a gradual approach, starting with improvement of animal-drawn equipment and simple food-processing machines. Local committees representative of the government, manufacturers and users of machinery have been found helpful in some areas in advising on the suitability of equipment for use in their area. Some governments have established the post of Research Engineer, whose job it is to analyse farmers' requirements and modify or make prototype machines to suit their conditions. Government experimental stations to establish standard patterns for farming main crops would also be most valuable.

The market is potentially vast. If it is to be developed, and mechanisation established satisfactorily, it is essential to make haste slowly and pay due regard to the lessons learned by bitter experience in recent years.

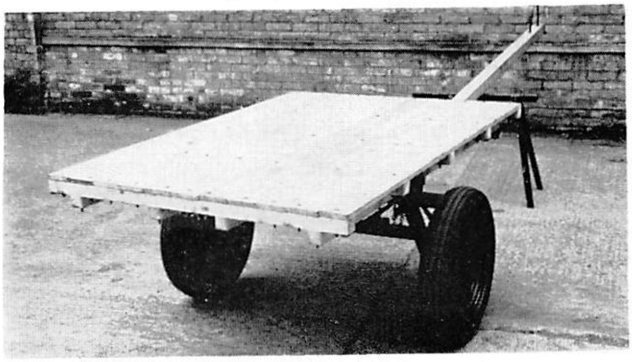
J.A.C.G.

ABOVE: Prototype portable thresher.
Trials under local conditions.

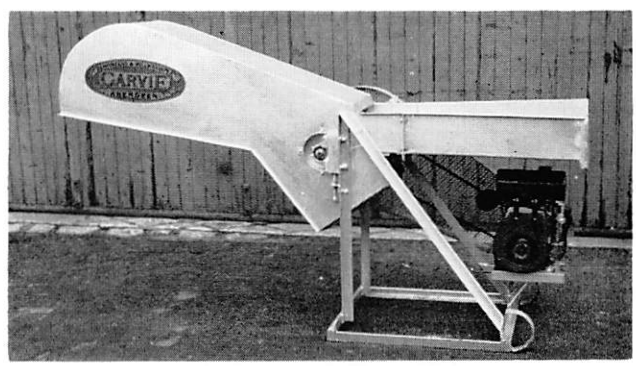


ABOVE: Chassis-tool-bar (Cultivator points mounted).
Plough, Digger, Seeder, etc., can also be mounted.

BELOW: Ox-cart, Chassis-tool-bar. Agricultural implement removed.
Platform body in position. Fittings for sides.



BELOW: Manufactured padi thresher.



AGRICULTURAL AVIATION

by D. B. BLACKETT, B.Sc., (Agric.), Ph.D.

A Paper presented at an Open Meeting of the Northern Branch in February, 1960.

THE use of the aeroplane as an agricultural implement is traditionally associated with countries having large tracts of cultivated land. This is particularly so where mono culture is practised where huge acreages of one crop are to be found.

The pioneer countries of aerial agriculture are U.S.A., Australia, New Zealand and U.S.S.R., who are reputed to have invented the technique of aerial spraying in 1922.

By and large, the agricultural aviation industry has been developed by using obsolete war-time equipment adapted for agricultural use—*e.g.*, Tiger Moth. Once the industry has become established, aircraft specially designed for agricultural use become a proposition.

In the U.K. aerial agriculture is still in the development period, and the bulk of the fixed-wing aircraft in use are Tiger Moths, whilst the operators are trying to widen the scope of their operations in an endeavour to establish the technique as an economic and basic part of British agriculture.

The Potential of Aerial Agriculture in the United Kingdom

If the aeroplane is to become an integral tool in the pattern of British agriculture, the period of operation must be spread over as many months of the year as possible to absorb the comparatively high overheads incurred in operating an agricultural aeroplane, instead of depending upon the occurrence of potato blight.

The 1959 season showed that planning an operation on the incidence of potato blight can have disastrous financial results.

There have been suggestions that some form of subsidy be given to help the established aeroplane operators. It may well be, however, that such aid could stifle the initiative of the industry and in all probability foster what could turn out to be a completely uneconomic operation. The success and future of aerial agriculture must rest between the farmer and the aerial operator. If the farmer can appreciate the advantages of aerial application techniques (and there is no better way of doing this than by showing a financial saving, and the aircraft operator can give a reliable and economic service) surely this would be exploiting to its maximum potential.

The following table gives some indication of the acreages which might be termed potential aircraft acres in England, Scotland and Wales :

Table I

Crop	*Acreage (Thousands)*	*Potential*
Rough Grazing* ..	5,027	Fertilizer application and weed control trace elements (bracken)
Permanent Grassland	1,230	Fertilizer application and weed control trace elements
Temporary Grassland	6,011	Fertilizer application and weed control trace elements
Forest and Woodland	3,500	Fertilizer application and insect control
Wheat	1,925	Fertilizer application and weed control
Barley	3,009	Fertilizer application and weed control
Oats	1,856	Fertilizer application and weed control
Potatoes	718	Blight control
Sugar Beet	435	Insect and virus yellows control
Brussels Sprouts* ..	47	Fertilizer application and aphis control
Peas*	152	Insect control
Orchards*	240	Insect and fungal disease control
Hops*	20	Insect and fungal disease control
Small Fruit*	32	Insect and fungal disease control

* Excluding Scotland.

The above chart does indicate that there is potentially sufficient acreage to merit the development of agricultural aviation, if, of course, the applications can prove to be economically worthwhile.

Fertilizer Application

The most important crop in the British agricultural pattern is grass, and it is the acres of grassland which offer the most scope for aerial top-dressing, whilst spring top-dressing of winter wheat with nitrogen also offers some considerable scope.

To increase the pay load of the aeroplanes, the fertiliser manufacturers are currently introducing more concentrated types of fertiliser. For nitrogenous top-dressing, urea containing 46% of nitrogen has recently been introduced with some considerable success. The need for more concentrated material has to date limited the scope of the aeroplane in use, and apart from experimental applications there has been no serious commercialisation of the more widespread and uplanding grazings. It may well be that the economics of upland farming may merit the development of aircraft designed to deal with lime and slag. Already ground contractors spread 10 million tons of lime every year, which does suggest that there is quite a considerable outlet for aerial application.

The main handicap to date to fertiliser application has been the absence of suitable dual-purpose aeroplanes. Instead of regarding top-dressing as the means of establishing an aircraft application industry, the approach has been to regard spraying as the most important and top-dressing merely to keep the aircraft and crew busy prior to spraying. Hence the equipment, which is primarily designed to be competitive for spray application, often proves to be of little economic value for top-dressing unless highly concentrated fertilisers are available.

The evenness of spread of fertiliser from the air is as good and in many instances better than that of the ground application.

With regard to the equipment used, emphasis has been given to the development of speedy loading on the ground. Usually the ground equipment consists of a hydraulically-operated quick-release loader, which fills the aeroplane hopper in one application.

Aerial Spraying

Basically, aerial spraying is a method of utilising the aeroplane as a carrier for a spraying machine. Normally, a spraying machine consists of a storage tank for the liquid, a pump and a boom, with nozzles to break the liquid into small droplets.

This is achieved by adapting the front cockpit in the case of the Tiger Moth as a spray tank and mounting a centrifugal pump beneath the engine. It is driven by the slipstream created by the propeller ; the booms are fixed to the bottom or trailing edge of the lower wing. Recently developed rotary atomisers are sometimes used.

The rotary atomiser is a new method of breaking the spray liquid into small droplets, and it is claimed that it is capable of a more rigid droplet size control and of giving droplets more uniform in size.

The atomiser consists of an inner perforated tube surrounded by an outer 80-mesh double-wrapped Monel gauze cylinder. The chemical is pumped through the perforated tube and centrifuged off the gauze cylinder. The cylinder is driven at approximately 15,000-r.p.m., but the speed is adjusted by altering the pitch of the windmill blades to quicken (finer droplets) or slow down the spinning cage (to give coarser droplets).

The biological success of aerial spraying is dependent upon the efficiency of the spraying equipment and the skill of the pilot to spread the drops produced on to the foliage of the crop, because the droplet is the means of carrying the chemical to the crop.

Droplet Size

The optimum droplet size is a matter of some debate. Some consider larger droplets (130–200 microns), are desirable, whilst others think smaller droplets are more efficient.

At an Agricultural Aviation Conference at Cranfield (September, 1959) there were varying viewpoints put forward, but there were no definite indications of what was, in fact, the correct droplet size.

Courshee described a laboratory experiment which suggested that a finer droplet may be preferable for good cover for a potato blight spray rather than larger droplets.

It is generally accepted that droplets between 60 and 200 microns are acceptable, depending upon the conditions prevailing.

The Fate of a Droplet

When the droplet leaves the nozzle or atomiser, there are three possible paths it may take :

1. It may fall on to the crop at which it is directed. This is influenced by (*a*) droplet size ; (*b*) speed of droplet.

2. It may fall on the ground.

3. It may remain airborne and drift away from the crop to be sprayed—*spray drift*.

Spray Drift

Spray drift may :

1. Become a toxic hazard.
2. Cause damage to neighbouring crops which are susceptible to the chemical being applied.
3. Reduce the efficiency of the spray.

It is influenced by :

1. The size of the droplet.
2. Air movement.
3. The distance of the nozzle from the target.
4. The velocity of the supporting airstream.

What exactly happens was best summarised by Dr. Hartley at Cranfield, who stated that more research into the subject was necessary rather than more theories. He expressed the opinion that small droplets were more likely to evaporate and therefore less likely to be collected on a crop. But others thought the recovery of a carrier on a crop was not necessarily related to that of the actual chemical.

Hartley also stated that strong winds were more likely to carry away more spray than a light wind, but they were less likely to deposit high concentrations of spray material in any one place.

Discussing experiments on spray drift from aircraft, Courshee suggested that with low flying, with a rigid control of droplet spectrum and the correct positioning of spray nozzles, it may be possible to reduce spray drift to

1% of the spray. This he thought equivalent to the land machine. Unless these precautions are taken, however, down-wind contamination could reach high levels. These conclusions were also put forward by Yeo, who also stated, to avoid hazards, that the spray should not be emitted into the wing tip vortices. He also suggested that the droplets or particles should be kept as large as possible.

The use of large droplets was also advocated by Little, of New Zealand, who gave details of applying hormone type of weed killers from the air. He reported that using water as a carrier, and large droplets, with a low, slow-flying aircraft, he had successfully carried out hormone spraying from the air in winds of 10–14 m.p.h. To do this, he maintained that high pilot skill, efficient equipment and a high standard of equipment maintenance were required.

The Scope of Aerial Spraying (see Table I)

Chemical rejuvenation of pastures.

Trace element application.

Insect control—pea moth, pea aphis, sugar beet aphis.

Disease control—potato blight, celery leaf spot.

Chemicals Used in Aerial Spraying

Their desirable quality is that they should be harmless to man and beast, harmless to other crops and non-corrosive to the aeroplane.

The chemicals used are :

- Organic and copper-containing fungicides for potato blight.
- D.D.T. for insect control, peas and brassicas.
- Systemic insecticides for aphis control on beet.
- Dalapon for chemical pasture rejuvenation.
- Various trace elements—*e.g.*, magnesium sulphate.
- Parathian pea moth control, not widespread.
- Hormone-type weed-killers—weeds in grasslands and cereals.
- Unspecified week-killer—bracken control.

It is not only the chemical and spraying equipment which are of importance, but it is how the chemical is formulated for use—*i.e.*, whether in water or in oil or in crystals.

A future development may make weed-killing from the air safer from the drift question, either by using invert emulsions water in oil (like mayonnaise) or by using crystals of the weed-killer.

Aircraft in Use in the United Kingdom

In common with other countries, the first aircraft to be used were developments of war-time machines. However, there are now specific machines in use—*e.g.*, E.P.9 Piper and the helicopters.

The machines which have been used or are in use in the U.K. are listed in Table II :

Table II

Aircraft Make	*Aircraft Type*	*Tank*	*Hop-per*	*Swath Width*	*Equip-ment*
Auster Agricola . .	Low-wing mono-plane	144 gals.	15 cwt.	81 ft.	Spray boom
Auster J.I.B. . .	High-wing mono-plane	48 gals.	5 cwt.	60 ft.	Spray boom
Auster Workmaster	High-wing mono-plane	100 gals.	—	60 ft.	Spray boom
D.H. Chipmunk . .	Low-wing mono-plane	50 gals.	5 cwt.	—	Spray boom
D.H. Jackaroo . .	Bi-plane	45 gals.	4 cwt.	51 ft.	Spray boom
D.H. Tiger Moth . .	Bi-plane	45 gals.	4 cwt.	39 ft.	4 rotary atomi-sers
Piper P.A.-18-A. . .	High-wing mono-plane	100 gals.	8 cwt.	50 ft.	Spray boom
Piper Pawnee P.A.-25	Low-wing mono-plane	110 gals.	10 cwt.	54 ft.	Spray boom
Prospector (E.P.9) . .	High-wing mono-plane	170 gals.	15 cwt.	81 ft.	Spray boom
Bell 47	Helicopter	40 gals.	—	45 ft.	Spray boom
Djinn	Jet Helicopter	40 gals.	—	60 ft.	Spray boom
Hiller 12C	Helicopter	50 gals.	—	54 ft.	Spray boom
Kolibrie H3. . . .	Jet Helicopter	44 gals.	—	66 ft.	Spray boom

Ideally, an agricultural aircraft should meet the following requirements (Ref., The Cornell Medical College).

1. Design forward fuselage and cabin structures to resist nominal crash as well as flight and landing loads.
2. Design aircraft structures to absorb energy by progressive collapse.
3. Design tubular structure to bend and fail outwardly away from the occupants.
4. Locate the passengers' and pilots' seats as far aft in the fuselage as possible behind the wing.
5. Locate fuel tanks in or on the wings—*not* between the firewall and instrument panel.
6. Provide space between the instrument panel and firewall (or nose section) to permit forward displacement of the panel and instrument cases.
7. Design the instrument panel to be free of sharp, rigid edges in range of pilot's head.
8. Fabricate the instrument panel of ductile material and/or use an energy-absorbing shield on the panel face.
9. Mount instrument cases on shear-pins and/or as low as possible.
10. Provide shoulder harness, safety belts, seats and seat anchorages of sufficient strength to resist failure up to the point of cabin collapse.

The above factors are, of course, concerned with pilot safety.

With regard to which machine does the better job—*i.e.*, fixed wing or helicopter—the consensus of opinion is that both machines, if properly handled, are capable of doing a good job. The helicopter can, however, be used in some situations in which it would be difficult to operate a fixed-wing machine ; *e.g.*, bracken spraying in the hill country. A drawback to the helicopter is that it cannot be used for applying solid fertilisers.

Economics and Future of Agricultural Aviation in the U.K.

An idea of the high operating costs incurred in this industry was given by Norman at the Cranfield Conference. He estimated that a small helicopter costs £36 10s. 0d. an hour to operate, whilst a fixed-wing machine costs £22. In the helicopter's favour, he considered it was capable of spraying 60 acres an hour, whilst the fixed wing could only do 40. This still gives an overall saving of 10% in favour of the fixed-wing machine, in addition to the very high initial cost of the helicopter ; *e.g.*, £10,000–£30,000 *v.* £2,000–£9,000 for the fixed wing.

It is obvious from these figures that as a business venture agricultural aviation requires a high capital outlay, and furthermore there are considerable running costs to be absorbed before a profit is shown on the books. Therefore, unless the operator can be sure of treating a minimum number of acres in a year, the whole operation becomes uneconomic. In his calculations, the operator has not only to consider his labour and capital costs, but the number of days on which an aircraft can normally fly in each month of the working season. This is essential in setting an aircraft's potential for a given operational month.

Operating an aircraft for agricultural work in the U.K. therefore requires some considerable thought and planning. An agricultural aviation service entails a considerable amount of expense and is at the mercy —as, of course, are all other agricultural operations—of the weather.

It is not surprising, therefore, to find that aircraft operators are demanding a financial guarantee from the agricultural merchants before they will allot an aircraft to his district. This does help insure them from very high losses should it turn out to be a non-blight year, and furthermore has the effect of making the merchant keener to book more acres for the aeroplane.

This is the situation at the moment—a new industry which could have a vast potential struggling to establish itself on an economic basis.

Now what of the future ? Clearly, the greater potential lies in top-dressing and bringing the more inaccessible regions into production, and it is not unreasonable to suppose that there may be specialised equipment developed for this purpose.

With regard to spraying the trend may take a very different form. Already patents have been taken out for a robot system of aerial spraying and there is talk of the flying spray tank. This trend does, of course, eliminate the pilot and may well be the future form of all agricultural spraying machines, doing away with the wheelings we have all had to put up with on sufferance and, of course, removing the risk to human life. On this latter topic the Ministry of Aviation, in conjunction with the N.A.A.C. Aerial Spraying Committee, are making every effort to ensure that all aircraft operators conform to a very high standard of conduct. This they feel will lead to a greater degree of pilot safety and prevent wildcat and irresponsible operators from bringing this new industry into disrepute.

SCHOLARSHIP AWARDS

The Scholarship Selection Panel has made the following awards for the 1962–63 Session of the N.D.Agr.E. Finals Course :

Dunlop Scholarship, value £250, to :

R. P. Starling, B.Sc. (Agric.), of Reading University.

Shell-Mex & B.P. Bursaries, value £50 each, to :

P. H. Bomford, B.Sc. (Agric.), of Reading University.

R. E. Goodfellow, N.D.A., of the Royal Agricultural College.

J. N. Tullberg, Intermediate N.D.Agr.E., at the North-West Wiltshire Area College of Further Education.

Mr. Starling, Mr. Bomford and Mr. Goodfellow have been accepted for the course at the Essex Institute of Agriculture ; Mr. Tullberg for the course at the West of Scotland Agricultural College.

APPOINTMENTS REGISTER

The Monthly Bulletin is once more available, and members may receive this regularly on request to the Secretary.

Open Meetings, 1962–63

The programme of meetings in London and the Branches is almost completed and a programme card will be sent to members in September.

As announced at the Annual General Meeting, London meetings will take the form of three whole day events, the dates being October 16th, 1962, January 15th, 1963, and April 23rd, 1963 (the Annual Conference). The Presidential Address by Mr. Cameron Brown will open the October meeting.

One oil one grease saves the farmer trouble

Esso Tractorlube (Universal). Summer or winter, for engine, transmission and hydraulics.

Esso Multi-purpose Grease H. For chassis, bearings and all points.

ELECTIONS

Approved by Council at their Meeting on the 26th June, 1962

ASSOCIATE MEMBERS		Atkinson, E.	Hertfordshire
		Curson, U. G.	Norfolk
		Old, J. L.	Warwickshire
		Russell, R.	Nottinghamshire
		Scowen, R. J.	Huntingdonshire
		Smith, N.	Cambridgeshire
	Overseas	Ditchfield, T.	Southern Rhodesia
ASSOCIATES		Watts, W. R.	Norfolk
	Overseas	Brerton, P. L.	Southern Rhodesia
		Green, L.	Uganda
GRADUATES		Harris, G. J.	Middlesex
		Hillcoat, J. D.	Wiltshire
		Moffatt, T. G.	Midlothian
		Symons, M. W.	Leicestershire
STUDENTS		Adjabeng-Ankrah, E. N.	Middlesex
		Adoffo, J. O.	Middlesex
		Kissi, A. O.	Middlesex
		Lewis, T. G.	Monmouth
		Thomas, K. M.	Staffordshire
		Tullberg, J. N.	Yorkshire

TRANSFERS

FROM ASSOCIATE MEMBER TO MEMBER		Lee, F.	Staffordshire
		Robinson, W. W.	Pembrokeshire
		Wallace, N. M.	Middlesex
FROM GRADUATE TO ASSOCIATE MEMBER		Calverley, D. J. B.	Hertfordshire
		Cowell, P. A.	Northumberland
FROM ASSOCIATE TO ASSOCIATE MEMBER		Snaith, F. I.	Hampshire
	Overseas	Taaffe, R. T.	Eire
FROM STUDENT TO ASSOCIATE	**Overseas**	McKinnon, E. E.	Indonesia
FROM STUDENT TO GRADUATE		Geeson, A.	Lincolnshire
		Henchy, J. W. F.	Suffolk

IN THIS ISSUE

Hepworth & Co. (Tunbridge Wells) Ltd.