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OF THE

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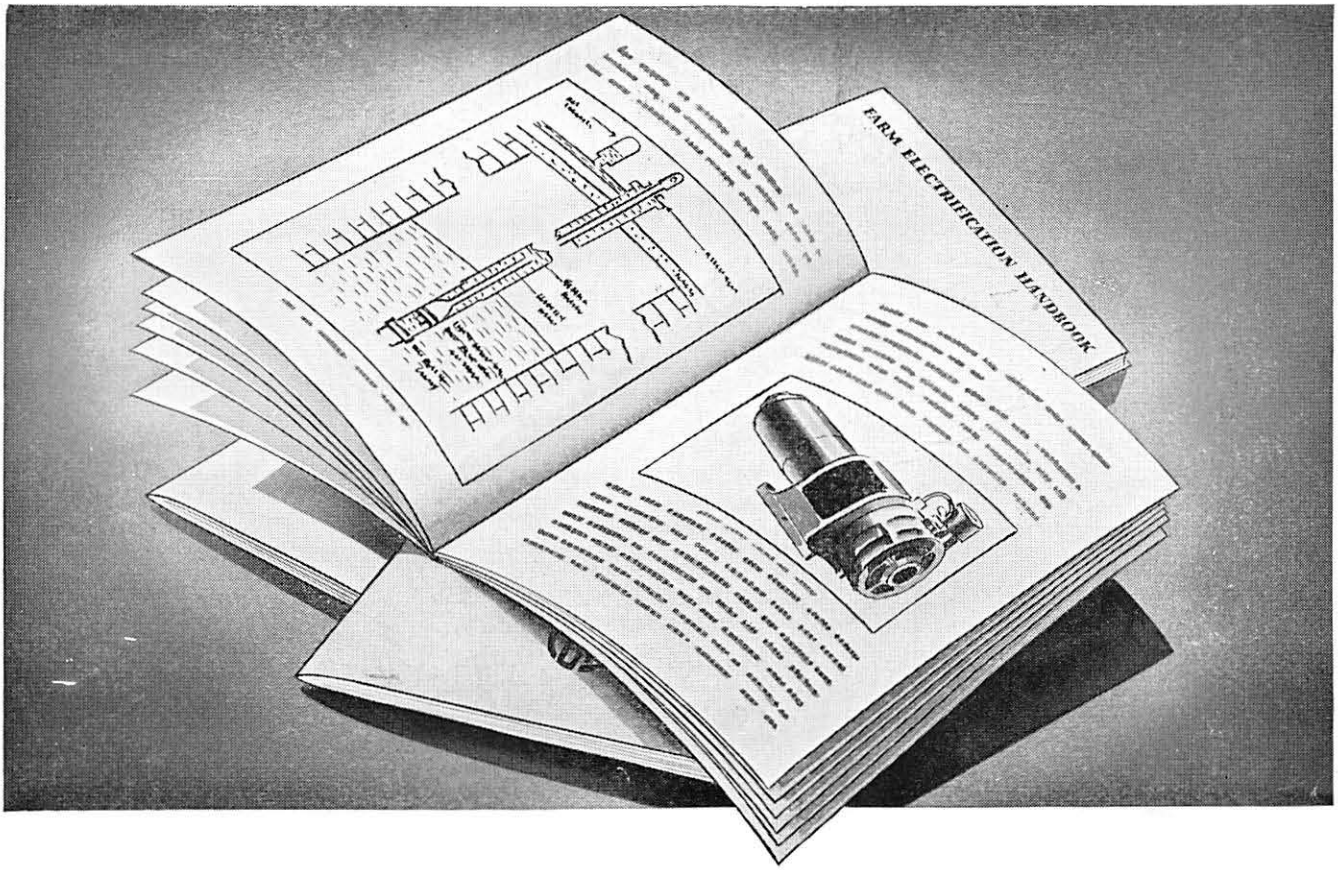
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JOURNAL AND PROCEEDINGS OF THE INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

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INSTITUTION NOTES

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Annual General Meeting and Luncheon

THE Annual General Meeting of the Institution was held on May 5th and was followed by the Annual Luncheon, at which the principal guest was Mr. Lionel Harper, President of the Agricultural Engineers' Association.

Mr. Harper, in his speech, referred to the probability of an early announcement about the provision of a National College of Agricultural Engineering, and emphasised the importance of this step to the industry.

Among matters discussed at the Annual General Meeting was the time of commencement of Open Meetings in London. After a two-year experiment of evening meetings, it has been found that attendances have been lower than at those previously held in the afternoon. It was unanimously agreed at the Annual General Meeting that Open Meetings should revert to the original time of 2.15 p.m. for commencement.

In presenting the Income and Expenditure Account and Balance Sheet for 1957, the Hon. Treasurer, Mr. W. J. Priest, referred to the credit balance on the year's working said this was largely due to the response received from members to the increased rates of the subscription. The Council were now in a better position to carry not plans already formulated.

Local Centres

At a recent meeting of the Council it was decided that the improved financial position of the Institution now permitted an increase in the grants to Local Centres.

These became effective as from January 1st this year. The Council was particularly pleased to be able to take this step in view of the increased activities of all seven Centres.

With the adoption of the new and enlarged form of Journal, it is now possible to include in each issue a Paper delivered to one of the Local Centres of the Institution. On pages 65 to 72 will be found those presented at a Conference on Soils and Cultivations organised by the East Anglian Centre and held in Norwich on February 12th, 1958. The Conference was very well supported, some 300 members and friends being present.

Certificates of Membership

Enquiries having been received from a number of members regarding the availability of Certificates of Membership, the Council has given the matter approval in principle and has under consideration a number of designs. A further announcement will be made in due course.

The Journal

Letters received from a large number of members indicate that the new form of the *Journal* is generally approved. It will be appreciated that costs have risen substantially and it remains important that the revenue from advertisements should be increased. The Secretary will gladly provide particulars of the cost of space to any member who may be in a position to assist in this way.

Overseas Representation

Mr. S. D. Minto has been appointed the Institution's representative in East Africa, following the resignation of Mr. J. S. Rideout, who has taken up farming.

Mr. Minto is the Officer-in-Charge of the East African Tractor and Implement Testing Unit, Nakuru, Kenya.

The Council's thanks are extended to Mr. Rideout for his services during his term as the Institution's representative.

Mr. R. B. Jessop, one of the representatives in Canada, has recently left that country for Kenya and has consequently relinquished this appointment. To him also the Council owe their thanks for his help.

Mr. J. A. Atkinson has been appointed to act in Australia (Queensland).

Careers Lectures

Following the initial lecture given by Mr. Bywater and Mr. Cashmore in November, 1957, the Council has under consideration the possibility of organising lectures on the subject of careers in agricultural engineering in various parts of the country. It is considered important that suitably qualified young men should be attracted into the industry and profession, and that it is one of the functions of the Institution to do so. Further particulars will appear in the Journal in due course.

That there is a relationship between labour requirements and the size and weight of the cattle on each farm is indicated in Fig. 1.

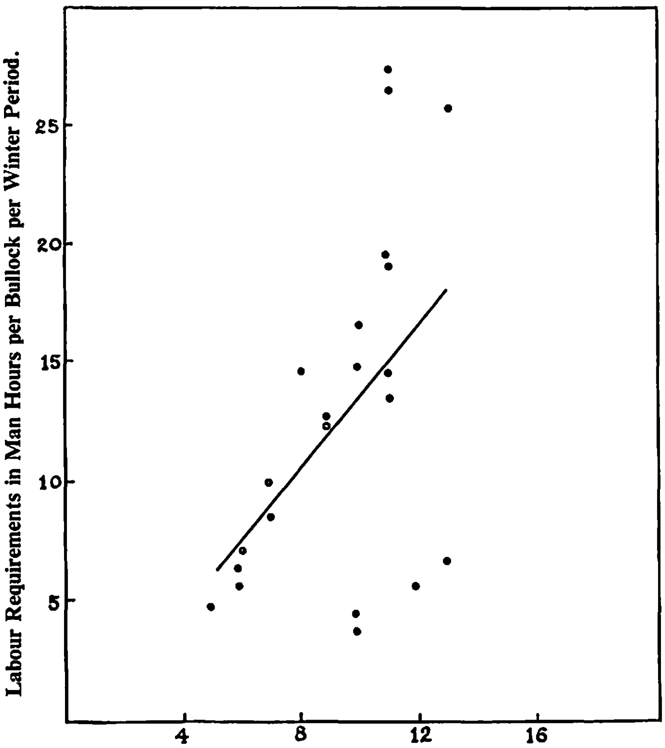

Fig. 1.

Although very few cattle-fattening enterprises are large enough to provide enough work for a specialised stockman, it is convenient to think in terms of a one-man unit. The regression* line in Fig. 1 shows the average quantity of labour required to tend bullocks of each weight. It suggests that labour requirements may reasonably vary between six and eighteen man hours per bullock, and that whilst a full-time stockman can be expected to look after more than two hundred small store animals, on the average enterprise he should not be expected to tend more than about eighty or ninety mature beasts :—

Average Weight of Bullocks (cwts.)	*Man Hours per Bullock per Winter Yarded Period*	*Bullocks per Stockman*
5	5·8	233
6	7·4	183
7	9·0	150
8	10·5	129
9	12·1	112
10	13·7	99
11	15·2	89
12	16·8	80

As standards for comparison these figures should be superior to any single estimate of labour requirements.

* $Yc = -2{\cdot}02 + 1{\cdot}57X$, $R = 0{\cdot}50$, $P = 0{\cdot}02$, when X equals the average weight of bullocks in hundredweights.

Nevertheless, the relationship between labour needs and the average size of beasts does little to explain those very high and very low labour requirements which are of particular interest.

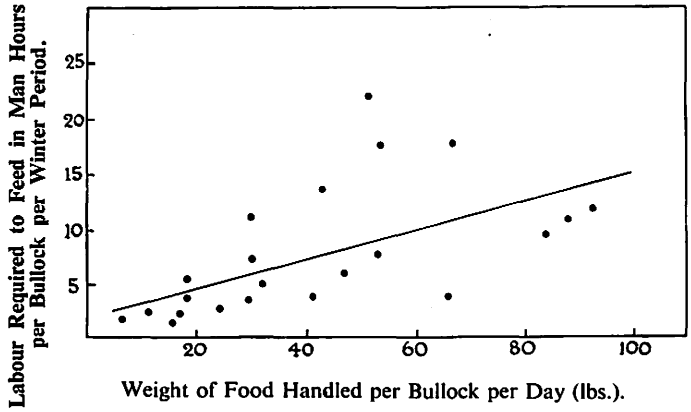

Fig. 2.

In Fig. 2 and Fig. 3 the labour of feeding is related to the weights of food handled by each stockman,* and to the distances travelled during feeding.†

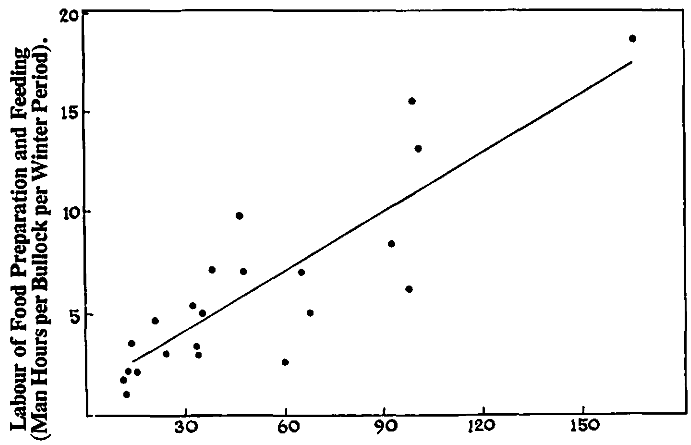

Fig. 3.

A simultaneous consideration of the influence of both weights and distances suggests a relationship with feeding times which is only slightly better than the simple relationship between feeding times and distances of travel.

This relationship is suggested as perhaps explaining four-fifths of the very wide differences observed in the labour efficiency of feeding. Certainly it goes a long way towards explaining those very high and very low labour

* $Yc = 2{\cdot}16 + 0{\cdot}13X$, $r = 0{\cdot}56$, $P = 0{\cdot}01$, where X equals the pounds of food handled per bullock each day.

† $Yc = 1{\cdot}21 + 0{\cdot}10X$, $r = 0{\cdot}87$, $P = 0{\cdot}001$, where X equals the yards travelled to feed each bullock each day.

‡ $Xc1{\cdot}23 = -0{\cdot}140 + 0{\cdot}041X_2 + 0{\cdot}093X_3$: $R1{\cdot}23 = 0{\cdot}89$. F value significant at 1 per cent. level. Where X_2 equals the pounds of food handled per bullock each day : X_3 equals the yards travelled to feed each bullock each day.

requirements which can not be explained by differences in the average size and weights of beasts :—

Observed and Calculated Feeding Times in Man Hours per Bullock per Winter Yarded Period.

Farm	*Observed Time*	*Weight of Food Handled per Bullock per Day in lbs.*	*Distance Travelled to Feed each Bullock each Day in yds.*	*Calculated Time*	*Unexplained Deviation from Calculated Time*
Three Highest Feeding Times—					
S	19·0	52	166	17·4	+1·6
D	15·7	67	98	11·7	+4·0
T	13·5	43	100	10·8	+2·7
Three Lowest Feeding Times—					
Q	1·1	16	12	1·6	−0·5
O	1·6	6	11	1·1	+0·5
P	2·1	17	16	2·0	+0·1

For example, on Farm S nineteen man hours were needed to feed each bullock throughout the winter yarded period. These particular animals weighed 11 cwts., and they received a ration which weighed 52 lb. Poor equipment and a badly-planned layout made it necessary for the stockman to travel 166 yds. daily in order to feed each animal. This appears to have been the major cause of low labour productivity.

Whilst high labour requirements on Farm D and Farm T are largely explainable in these same terms, materials handling had been reduced to a minimum on the farms where feeding was carried out efficiently. For example, on Farm Q the stockman travelled 12 yds. and handled 16 lb. of food in order to feed each animal. He took 1·1 man hours to feed each bullock throughout the winter period, and this performance compared favourably with a calculated or expected time of 1·6 man hours. On Farms O and P the stockman walked 11 and 16 yds. to feed 6 and 17 lb. of food to each beast whilst the remainder of each ration was self-fed. Here again calculated labour requirements of 1·1 and 2·0 man hours per bullock do not differ very greatly from the 1·6 and 2·1 man hours which were observed to be required in practice.

Although feeding tends to be the more time consuming job, some 30 to 40 per cent. of the average stockman's time is required to litter yards. In this sample the labour of littering varied from 1·1 to 13·5 man hours per bullock, and weights and distances are again suggested as important causes of the wide variation in labour use. In addition, particular stockmen either distribute small quantities of straw each day, or they use larger quantities but litter less frequently. Together these three variables* are suggested as perhaps being responsible for 70 per cent. of the variation in labour use.

* $Xc1{\cdot}234 = -2{\cdot}720 + 0{\cdot}059X_2 + 0{\cdot}098X_3 + 0{\cdot}620X_4$: $R1{\cdot}234 = 0{\cdot}85$. F value significant at 1 per cent. level. Where X_2 equals the pounds of straw distributed daily for each beast. Where X_3 equals the yards travelled to litter each bullock. Where X_4 equals the frequency of littering per week.

In these terms extreme labour requirements certainly become more explainable. For example, the stockman taking the most time litters every day, and he travels 26 yds. to distribute and spread 160 lb. of straw for each beast. In this very extreme example an observed labour requirement of 13·5 man hours a bullock agrees almost exactly with a calculated requirement of 13·6 man hours. It is apparent that the labour of littering varies partly as a result of differences in the quantities of straw which farmers wish to convert into manure, partly as a result of differences in the suitability of their equipment, yard layouts and handling methods.

This analysis provides only sketchy evidence on which to base general principles, but it does, I think, serve to emphasise the importance of effective materials handling as a means to labour efficient feeding and littering. It suggests that the mechanisation of these jobs should have the efficient handling of materials as its main object, and that machines and methods should be developed with a view to reducing both the distances and the handling involved in work of this sort. In industry fork-lift trucks may be employed, and materials stored on pallets can be bulk handled and mechanically loaded and unloaded. The labour of feeding and littering would be greatly reduced if some similar system could be developed in agriculture.

Mechanisation, the Scope and the Economic Limitations

At present there would appear to be only three or four basic methods of distributing food and litter. Food and litter may be distributed more or less manually. This, of course, is the least efficient method and involves many journeys with bales, barrow or pitchfork. Secondly, materials may be handled in bulk—for example, by tractor and trailer or on a smaller scale by trolley. Thirdly, food and litter can be stacked where they will be required, preferably under the same roof as the animals that are to utilise them. Finally, there is the possibility of self-feeding.

That there are wide differences in materials handling, and in the labour efficiency of these methods, can be illustrated by reference to average labour requirements when cattle are fed in one or other way. In terms of the man hours required to feed a cow throughout the winter, bulk handling requires 13 man hours, adjacent stacking 10 man hours and self-feeding 5 man hours.

Arable work may be mechanised in order to save labour, but machines may also be adopted in order to achieve greater precision, to reduce the labour that must be undertaken in busy periods, or in order to obtain a timeliness of cultivations and a better partnership between man's efforts and natural forces.

In contrast, the mechanisation of livestock jobs can usually be regarded as a simple substitution of machinery for labour, and further mechanisation can only be justified if the annual cost of extra machinery is to be offset by the annual value of the labour that it will save.

TABLE 1

Man Hours per Year

	*Per Cow**	*Per Sow*	*Per Fattening Pig*	*Per Bullock*	*Per 100 Poultry†*
Feeding	15	19	6	8	26
Cleaning and Littering	14	13	6	5	25
Milking	42	—	—	—	—
Dairy Work	17	—	—	—	—
Egg Handling.. ..	—	—	—	—	45
Miscellaneous.. ..	9	5	1	4	8
Total	97	37	13	17	104

Average labour requirements for different jobs and different livestock enterprises are presented in Table 1. Dairy cows and breeding sows occupy the most labour, but with the exception of milking and egg handling the labour cost of any particular job is not normally a very large part of the total labour cost. If we assume a wage rate of 4s. an hour, we may conclude that some fully automatic method of feeding or of cleaning and littering dairy cows would be justified if it could be installed and maintained at an annual cost not exceeding £3 per cow.

TABLE 2

Annual Labour Cost in £'s on the One-Man Unit

	Dairy Cows	*Sows*	*Fattening Pigs*	*Poultry*
Feeding	84	278	250	135
Cleaning and Littering	78	190	250	130
Milking	234	—	—	—
Dairy Work	95	—	—	—
Egg Handling ..	—	—	—	234
Miscellaneous ..	50	73	41	42
Total	541	541	541	541

Table 2 assumes a wage rate of 4s. an hour, and indicates the average cost of labour for different jobs and for one-man units. On the typical one-man dairy unit the scope for fully mechanised feeding or littering would appear to be limited to an additional annual expenditure of £80, and to something less than this if these jobs are to be only partly mechanised. Whether these jobs could be extensively mechanised without increasing expenditure by more than the amount suggested is not for me to interest, a life of ten years and modest repair and operating costs, we must look for equipment which will reduce the labour of feeding or littering to a fraction of that now used, and which when applied to the one-man dairy unit can be provided at an initial cost of no more than about £350.

* This data relates to herds housed in yards and milked in parlours. Labour requirements in cowsheds average 126 man hours per cow a year.

† These figures refer to birds kept in deep litter houses. Average total labour use amounts to 168 and 197 man hours per 100 birds per year in cafeteria and static batteries.

Because much of their time is occupied with milking or egg handling, feeding and littering assume less importance in the day of a full-time cowman or a specialised poultryman. In contrast, these two jobs account for a large part of the work on pigs or on other cattle, and there would appear to be particular scope for much more mechanised feeding, cleaning and littering in intensive piggeries.

In Tables 1 and 2 the figures relating to dairy cows and to poultry refer to cows housed in yards and milked in parlours and to poultry kept on deep litter. These methods of management are among the more labour efficient of the systems in general use. Twenty-five per cent. more labour is required in cowsheds, and the labour efficiency of extensive poultry units is about equal to half the efficiency achieved in deep litter houses. It is therefore not surprising that much effort in the past has been directed towards the discovery of better methods of tending dairy cows and poultry.

From Table 2 it is clear that the feeding and the cleaning and littering of pigs are the two jobs which now occupy the most time in the day of a specialised stockman. Yet even today milking and egg handling occupy large quantities of labour on the dairy or poultry farm. These are the jobs which offer the most scope for further mechanisation. They would each justify substantial expenditure in order to obtain a worthwhile saving in the labour that they now occupy.

Mechanisation at the Present Time

A study of present practice suggests that much could be achieved by a fuller and more effective use of the equipment that is now available. In particular, jobs which are carried out at the farmstead cannot be effectively mechanised without reference to the suitability of both the buildings and the organisation of lbaour.

A simple example will serve to illustrate that equipment can play an important role if this is appreciated.

My example is concerned with the distribution of bulky foods to yarded cattle and with the correct use of a trailer. On the majority of farms the mangers are not accessible from outside each yard, and if a trailer is used to distribute feed it must be taken inside the yards. This makes it convenient to employ two men on the job, one to drive the tractor and a second to open and shut the yard gates. The labour involved in distributing silage or hay to three yards of cattle then involves eighteen operations, eighteen transports and twelve delays :—

1st Man

⇨1 Walk to first yard.
○1 Open yard gate.
D1 Wait for 2nd man.
○2 Shut yard gate.
⇨2 Walk to manger.
○3 Fork fodder into manger.
⇨3 Walk to yard gate.
○4 Open yard gate.
D2 Wait for 2nd man.
○5 Shut yard gate.

Repeat in 2nd and 3rd yard.

2nd Man

D1 Wait for 1st man to open gate.
⇨1 Drive to manger in yard.
○1 Fork fodder into manger.
⇨2 Drive to yard gate.
D2 Wait for 1st man to open gate.
⇨3 Drive tractor and trailer to next yard.

Repeat in 2nd and 3rd yard.

○ = 18
⇨ = 18
D = 12

If the yards are adapted to this method of feeding, the mangers will be accessible from outside each yard, and the same job will only involve three operations and four transports :

⇨1 Drive to 1st yard.
○1 Fork fodder into the manger.
⇨2 Drive to 2nd yard.
○2 Fork fodder into the manger.
⇨3 Drive to 3rd yard.
○3 Fork fodder into the manger.
⇨4 Drive to 4th yard.

○ = 3
⇨ = 4

This simple example indicates something of the advantage to be obtained by bulk handling. It illustrates that the benefits of mechanical handling may only be obtained when machinery is used together with suitable buildings and appropriate methods. Where this is the case, trailers, foreloaders and tractor-mounted scrapers can be used to reduce the labour of livestock tending to far below the figures suggested in Table 1.

Machine Milking

If modern methods are used there is very little materials handling involved in milking, and labour efficiency would appear to depend more on a wider and better use of the excellent equipment that is now available.

The results of a large number of time studies suggest average rates of milking which are far below the rates that should be obtainable with this equipment. They indicate average rates of machine milking of 13 cows per man hour in cowsheds and of 17 cows per man in parlours.

The low average rate of milking in cowsheds is partly a result of bad routines and poor layouts, or it arises simply because many cowmen are provided with an inadequate number of milking machines.

The Average Cowshed

$$\text{Rate of Milking} = \frac{\text{Average number of machines per man}}{\text{Average machine on + Average machine off time in seconds per cow}} \times 3{,}600$$

$$= \frac{2{\cdot}2}{450 + 168} \times 3{,}600$$

$$= 12{\cdot}8 \text{ cows per man hour.}$$

If we consider the capital that has been invested in modern milking parlours, the average efficiency of parlour milking is particularly disappointing. The sole object of parlour milking is to save labour, yet it is very common to find quite slow milking cows being milked in parlours by cowmen equipped with only two units. It appears that men and machine arrangements more suited to cowsheds are frequently retained in parlours :

The Average Parlour

$$\text{Rate of Milking} = \frac{\text{Average number of machines per man}}{\text{Average machine on + Average machine off time in seconds per cow}} \times 3{,}600$$

$$= \frac{2{\cdot}6}{450 + 114} \times 3{,}600$$

$$= 16{\cdot}6 \text{ cows per man hour.}$$

If these performances are to be improved upon, we must seek the answer to two problems. Firstly, how much work is involved in milking a cow and how can the work be reduced ? Secondly, given some improved method of milking, what is the best number of milking clusters with which to equip each cowman ?

With a satisfactory system of in-pipe or in-churn milking, or when milk is tipped to churns in the cowshed there is no need to carry the milk of each cow to the dairy, and the work on each cow need not exceed 150 secs. Under these circumstances a man has time to use three machines on cows averaging $7\frac{1}{2}$ mins. to milk out, and using a full but efficient routine he will milk 22 cows an hour. A correct routine ensures maximum machine utilisation, and if the clusters are disinfected as part of the milking routine the time required to transfer a machine from one cow to another is about 50 secs.

$$\text{Appropriate number of machines} = \frac{\text{Average machine on + Average machine off time}}{\text{Work on each cow}}$$

$$= \frac{450 + 50}{150} = 3$$

The labour normally involved in cowshed milking can be halved in these ways, and although the cowman handles three milking units he has some 50 secs. left for eventualities in each machine cycle :

$$\text{Rate of Milking} = \frac{\text{Machines per man}}{\text{Average machine on + Average machine off time in seconds per cow}} \times 3{,}600$$

$$= \frac{3}{450 + 50} \times 3{,}600$$

$$= 21{\cdot}6 \text{ cows per man hour.}$$

Because of the speed with which it is done, there is considerable doubt as to whether disinfecting the clusters during milking serves any useful purpose. If this job is omitted the work in a parlour need not exceed 120 secs. per cow, and the time required to transfer a machine from one cow to another will be 14 or 90 secs., the much greater machine off time being unavoidable in parlours equipped with a milking cluster to every standing.

With cows averaging $7\frac{1}{2}$ mins. to milk out, and a milking cluster to each pair of standings, we may therefore expect a man to operate three machines and to milk 23 cows an hour in a parlour :

$$\text{Appropriate number of machines} = \frac{\text{Average machine on + Average machine off time}}{\text{Work on each cow}}$$

$$= \frac{450 + 14}{120} = 3$$

$$\text{Rate of Milking} = \frac{\text{Machines per man}}{\text{Average machine on + average machine off time in seconds per cow}} \times 3{,}600$$

$$= \frac{3}{450 + 14} \times 3{,}600$$

$$= 23{\cdot}3 \text{ cows per man hour.}$$

In parlours equipped with a milking cluster to each standing the greater time during which machines are out of use results in a longer machine cycle. This, in turn, may enable a cowman to handle one extra machine and to milk 27 cows in an hour :

$$\text{Appropriate number of machines} = \frac{450 + 90}{120} = 4$$

$$\text{Rate of Milking} = \frac{4}{450 + 90} \times 3{,}600$$

$$= 26{\cdot}7 \text{ cows per man hour.}$$

The speed of milking may be raised in two ways.

It may be raised by encouraging the cows to milk out in approximately the same time that is required to operate a particular number of machines. For example, a more efficient pulsation ratio may be introduced or a few slow-milking cows may be culled in order to reduce the average milking-out time of a herd from $7\frac{1}{2}$ to $6\frac{1}{2}$ mins. With this new milking-out time the cowman may still operate a four-cluster, four-standing parlour, but he may now milk up to 30 cows an hour :

$$\text{Appropriate number of machines} = \frac{390 + 90}{120} = 4$$

$$\text{Rate of Milking} = \frac{4}{390 + 90} \times 3{,}600 = 30$$

If these cows were encouraged to milk out even more quickly the cowman would not have time to handle four machines and to carry out the full milking routine except by leaving machines on the cows longer than is necessary. Any further increase in the speed of milking then depends upon a reduction in the work on each cow. For example, by omitting a number of optional jobs such as machine stripping and the use of a strip cup and by feeding concentrates at some other time the labour of parlour milking can be reduced to round about 80 secs. per cow. A man using the optimum number of units can then milk up to 45 cows an hour. This optimum number of units would be four if the cows could be persuaded to milk out in just over 4 minutes.

A rate of milking of 45 cows per man hour is, of course, the theoretical maximum under the circumstances that I have assumed and unlikely ever to be achieved in practice.

Nevertheless, it does seem that substantial quantities of labour could be saved by using existing milking equipment more efficiently.

In addition, we may perhaps argue that the speed with which cows can be persuaded to give their milk is relatively unimportant, and that we should seek better methods and equipment which will reduce the work to be done on each cow. Getting the cows in and out of an ordinary parlour and udder washing are the two operations which occupy the most time. The time required to fetch and let out cows is greatly reduced in the herringbone parlour, but as they normally occupy the most time these two jobs may also offer the most scope for improvement.

Throughout this Paper mechanised livestock tending has been considered as a simple substitution of machinery for labour. Whilst this is true of the work that has been considered, there are one or two exceptions that should, perhaps, be mentioned. For example, in order to choose correctly between a deep litter house and a static or cafeteria battery, we must consider their relative costs, but also the higher yields which may be obtained in a battery as a result of systematic culling.

Similarly, if we assume a simple substitution of machinery for labour, we may conclude that the labour of feeding cattle is reduced by extending the grazing period and that mechanical grazing should be reduced to a minimum. Natural grazing is certainly the most labour efficient method of feeding cattle, and any extension of mechanical grazing and of the period when cattle are housed can only be justified if the extra labour required can be offset by increased yields and greater livestock production.

Having regard for the economic limitations and for the scope for more mechanised livestock tending, I myself do not visualise the widespread use of automatic or semi-automatic equipment for such jobs as feeding, cleaning and littering. The work in an intensive piggery or poultry unit has much in common and in the future battery methods may, perhaps, be aplied top piggeries. More generally, I conclude that there is much scope for a more widespread use of the equipment already available, that in many cases this could be used to far greater advantage and that the farmer will be well served by inventions and improvements on the present pattern.

That there are very wide differences in labour efficiency and therefore much scope for improvement on individual farms is well illustrated by figures showing the wide differences in labour use in particular farm samples :

Labour Use in Man Hours a Beast per Year

	Minimum	*Maximum*	*Average*
Fattening Pigs	4	28	13
Breeding Sows	7	75	37
Poultry	1	6	2
Yarded Bullocks .. .. (per six months' Winter Yarded Period)	5	27	14

These differences chiefly arise because of differences in the labour efficiency of buildings, equipment and work methods.

In considering the work which appears to offer the most scope for further mechanisation, I have ignored a number of jobs which are of less importance because they have already been extensively and successfully mechanised. Today there need be very little labour involved in milling and preparing feeding-stuffs, whilst in-churn milking, together with immersion cleaning, greatly reduce the labour involved in washing up milking equipment. These are outstanding examples of the application of machinery and of new methods to livestock husbandry, and there are many others, ranging from catfeeria poultry batteries to the convenience which is obtained by baling hay, straw and silage. Some are the product of the mechanical engineer, others have been developed by chemical and electrical engineers. The invention of the internal combustion engine gave impetus to the mechanisation of crop production. Electrification is giving a similar impetus to the mechanisation of work at the farmstead.

DISCUSSION

PROFESSOR A. N. DUCKHAM: It is a pleasure and privilege to be allowed to open the discussion on this very thoughtful Paper.

I suppose part of the duty of the opener of a discussion is to try to pick holes in the Paper read by the main speaker. I am going to make only two points. The first is picking a little bit of a hole, and the second is by way of an observation.

First, what does Mr. Brayshaw mean by requirements? As I see it, by "requirements" he means the time he observed was taken for a particular job. This is not necessarily the same as the time that is really needed for the job; *i.e.*, it is not necessarily the time "required." If I might give a simple example, in some research that one of my colleagues is now doing at Reading, we find, like Mr. Brayshaw, that about 7½ minutes is the average milking time, or at least the average time the cluster is on the cow. We are equally certain that this is much too long. It may not, therefore, be entirely wise to build up standards which one recommends to farmers all over the country if they are based on practices that, from the husbandry point of view, are hard to justify. So I should like Mr. Brayshaw to clarify that point.

My second point is by way of an observation or point for debate. It relates to the scope for mechanisation. Mr. Brayshaw says that, in mechanisation in the field, we use the machines to save direct labour and to do the job better and on time. But he seems to suggest that there are not the same opportunities in livestock tending for using machines to do the job better and on time. He thinks we have to look at mechanisation in livestock tending primarily in terms of the human labour saved. Personally, I am rather doubtful about that. I think we have to consider mechanisation from a husbandry point of view—better care of the animals as well as saving in terms of man hours. We have also to consider mechanisation from the point of view of the effect on the man; for example, getting rid of unpleasant jobs—man-handling silage or dung.

I should very much like to hear something about whether we could make better use of the cutter and blower principle. The Americans use it much more than we do for sucking up food, for straw, and for litter. Can we use it also for sucking up dung?

MR. BRAYSHAW: It is true that a number of indirect benefits are often associated with the mechanisation of livestock work. I have suggested that 80 to 90 per cent. of the average stockman's time is occupied with feeding and littering. This is work which requires care, but which does not call for any very high degree of skill. If these jobs can be simplified, either by mechanisation or by the use of better methods, then a skilled stockman is left with more rather than with less time in which to apply his special skills.

Alternatively, there must be many small dairy and mixed farms in the country on which a substantial reduction in the routine work on livestock could provide the extra time and the timeliness with which to obtain higher crop yields and to make better quality forage. Nevertheless, the primary object of mechanising livestock work is to save labour. The labour saved by machinery may be used to achieve more efficient crop or livestock husbandry, and this will be reflected in higher yields. Yet the same end might be attained by employing more labour in preference to machines. For this reason, I prefer to consider the mechanisation of livestock jobs as a simple substitution of machinery for labour, and to ignore the secondary effects which will vary according to the circumstances on particular farms, and which arise when more labour is made available, and not necessarily as a result of mechanisation.

Professor Duckham asks whether my figures refer to the average times taken for particular jobs or to the times really needed to undertake these jobs. They refer to the times taken and not to any work study evaluation of the times considered to be necessary. The difference between the labour used on very many farms and the labour which would be needed under optimum conditions is often very great. I think that comparative standards based upon the labour really needed with efficient methods would set an impossibly high standard of performance for the many farmers whose buildings and equipment leave much to be desired. The ideal would be to have two sets of standards. Comparative standards based on average performance provide a very convenient method of diagnosing a labour problem. They indicate where and to what extent there is a serious labour problem on any particular farm. Standards based on the time required to undertake work under optimum and defined conditions would serve to indicate both the means and the scope for improvement.

MR. E. V. KNIGHT: Mr. Brayshaw mentioned a figure of £350 for alterations in a dairy unit. It sounds an optimistically small figure to me, but even £350 for a small farmer can seem an awful lot.

There are other limitations, too. Let me pick out one or two. I am not anti-mechanisation, but I am trying to look at it from the practical man's point of view.

There are the livestock themselves. One cannot treat an animal as though it were a bit of machinery. One cannot switch it on and switch it off and treat it in that way. Before one sets out to mechanise a livestock unit of any kind, one has to use a good deal of discretion. The pros and cons have to be weighed up. You may save labour, but you may lose on production. For that reason, Mr. Brayshaw may have given the impression, unwittingly, that in the case he quoted where 19 man hours were spent per beast in the winter period as against 1·1, the balance of 18 man hours was sheer waste.

I do not agree with that point of view. Someone has to go and look at the stock, and the 18 extra hours the other fellow spent were not all wasted. It is an exorbitant amount, I agree. But one has to deduct something for the time taken to look at the animals.

MR. BRAYSHAW: From the figures in Table 12 I suggested that in the typical one-man dairy unit the scope for fully mechanised feeding or littering is at present limited to an additional annual expenditure of £80, and on certain conventional assumptions to an initial expenditure of no more than about £350. Mr.

Knight suggests that £350 seems a lot for the small farmer to invest in re-organising his cowshed, but, of course, £350 simply represents the maximum installation cost which could be present be justified in order to make the work of either feeding or littering fully automatic on the one man dairy unit. The figure of £350 refers, therefore, to quite a large unit, and I suggest it only to emphasise the economic limitations which at present restrict the development and use of automatic or semi-automatic equipment.

Although he did not put it in this way, Mr. Knight emphasised that there is the possibility of saving 2½d. worth of labour and of losing £5 worth of output. This is indeed a possibility of great practical importance. Labour productivity may be simply defined as the ratio between output and labour input, and high labour productivity is as dependent on a high output as upon a low labour input. As Mr. Knight suggests, the output side of this ratio tends to be the more important cause of high or low productivity, and it will rarely be profitable to economise in the use of labour at the expense of output. On the average farm, and at the present level of prices, any economies that can be obtained by saving labour or any other input are likely to be far less than the opportunities that still exist for reducing unit costs of production by spreading overhead costs over a greater output.

Finally, Mr. Knight suggested that before buying machinery the farmer should sit down and decide what he can do without. I entirely agree with him. One of the greatest dangers of haphazard mechanisation is that it is only too easy to end up by being over-capitalised. This is particularly true on the small and medium-sized farm where it is sometimes difficult to justify anything more than modest expenditure on machinery. Mechanisation is ill-advised and unjustified if it cannot be payed for out of increased output or by an effective reduction in other expenses. It may be easy to save labour in theory but more difficult to save it in practice. It is still more difficult not only to save labour but to re-employ it productively. There will only be a small proportion of farms in this country where mechanisation would enable the farm staff to be reduced by one man. If only a part of a man's time can be saved he must be productively re-employed for the saving to be effective. This often implies intensification and a need for more capital. Alternatively, mechanisation on the small farm can be directed to those points where it will be effective without intensification—rush periods, reductions in overtime, and so on. These considerations do limit the scope for mechanisation, particularly on the smaller farm.

MR. K. J. BENFIELD : I share one or two characteristics with Mr. Knight. I come from the same county and am a farm manager intensely interested in the commercial running of some fairly large livestock enterprises.

I should like first to emphasise a point made by Mr. Knight—that we must not lose sight of the livestock side of this job. After all, if you reduce livestock feeding to its absolute minimum you dry feed your calf once a week. When it gets a bit bigger you self-feed it on silage in a yard made of straw bales, which are gradually used as litter. You can bring down the labout cost to something comparable with the figures given in the Paper, but I am not very happy about the type of animal or livestock product you produce.

Looking at it from the other side, we must pursue to the absolute limit the attempt to reduce fatigue and physical work. Livestock work makes a heavy demand on physical output, and anything we can do to reduce that requirement we must push on with.

MR. BRAYSHAW : Yes, I agree with Mr. Benfield that we must consider labour use and mechanisation in relation to the entire farm. Whenever capital investment in machinery or in any other form is contemplated, it is necessary to look at the farm as a whole and to consider the advantages of alternative forms of investment. I think it was Mr. Knight who earlier in the discussion suggested that farms should sit down and decide what machines they could do without. In this connection, I am quite sure that some farmers should not be buying more machines, but should be spending more money on fertilizers and on other expenditure designed to increase farm output rather than to economise in inputs.

MR. F. C. RICHARDS : I should like to refer to a development which some of us believe to be quite significant at the present time. It is the method of taking all the feed to the animals and not allowing any grazing at all. That sounds crazy to many people on first hearing, but there are farmers who are doing it, and the results are quite spectacular, with certain reservations. One farmer has said that he is getting 100% extra utilisation from his grassland. That is optimistic. I do not think it will turn out to be anything like that. On the other hand, another farmer who has been working the system for a number of years now claims 50% extra utilisation. Research workers at Edinburgh put the figure at 25 to 30%, which is quite considerable. Greater utilisation of products from the land is surely of great importance to us.

MR. W. S. SHATTOCK : Mr. Brayshaw mentions the time taken for milking on the various farms. Did any of the standard figures used for comparison include sampling and recording at any time? There is no reference to this in the figures in the Paper. On farms today one finds many of the bottlenecks throw back to these points, whether the recording is weekly or more particularly daily.

I was interested in the remarks about palletisation. I think mobile units for moving feed to livestock, whether special trailers to fill containers at fixed points near the stock or pallet units to be transported to these points, will play a greater part than mechanical conveyors, the reason being that on so many farms there are immovable obstacles. The cost and difficulties of altering buildings to accommodate conveyors or taking them across open yards will constitute numerous problems. It may be cheaper and easier to consider carrying the feeding stuffs in units and distributing these to different sites. Another point is the mechanising of feeding stuffs which, up to now, have only been tackled from one fixed site and not carried any further. It is possible that on certain farms a less costly answer would be the provision of a mixer-cum-trailer. This unit could mix the feed and be used for transport to the place where it is to be fed and there mechanically discharged into a container.

A previous speaker referred to hay and how much worse the quality is today with baled hay. Many farmers could improve their methods of making by re-learning old techniques. The baler provides the farmer with a packaged unit of fodder easily handled and easily rationed ; he knows after harvest how much he has to see him through the winter and whether he must buy more. These are the main advantages considered by most people, but improved methods of making must be used to obtain " good hay." Agricultural engineers have now made the baler so mechanically efficient that it will bale poorly-conditioned or over-wet material. It is sometimes questioned whether these are good features because older models failed to bale damp hay and farmers had to stop work. It may be that future machines could be designed capable of adjusting themselves to allow for hay moisture content or being adjusted to reject hay unsuitable for baling. However, the immediate task must remain to achieve more even drying of the hay.

MR. BRAYSHAW : Mr. Shattock asks whether the times I quote for milking include an allowance for sampling and recording. The average times are based on a sample of farms on which milk was recorded on only one day a week in the majority of cases. All other times provide adequate time for recording.

I do agree that the mechanisation of livestock feeding tends to stop short at mechanical milling and mixing, and that the use of pallets in conjunction with a tractor-mounted fork lift may be better than a conveyor system as a method of distributing feed mechanically. The labour involved in any one livestock job is usually relatively small, and it is not easy to justify the use of a specialised and expensive machine. The tractor provides a mobile power unit, and a tractor-mounted fork lift need not be expensive. It could offer the farmer some of the advantages that the fork lift truck has given to industry. So much farm labour is concerned with materials handling.

MR. N. W. DILKE : I wonder if manufacturers in this country pay enough attention to management when they bring new machines on to the market. It strikes me that dealers are often only interested in selling a machine and do not give enough consideration to the machine in relation to the management of the farm as a whole. As an instance, in Mr. Brayshaw's Paper the flow chart of the new method for yard feeding still shows one man forking from the trailer to the manger.

For a considerable time there have been moving floor trailers in the form of muck spreaders, but up to now not a single manufacturer in this country has marketed a side delivery to carry feed from this type of trailer direct into the manger. A simple bunk feeder of this nature would reduce labour costs and fatigue, and give the small farmer more scope to look at his livestock and attend to other management problems. Is it that manufacturers would rather sell the moving floor muck spreader for one job and other types of trailer like the hydraulic tipper for other jobs ?

Similarly, the front mounted hydraulic loader is an excellent basis for a fork lift mechanism which would allow the smaller farmer to use unit handling with pallets or stillages at a reasonable price. Once again the larger manufacturers have neglected this field, although systems of this type are being manufactured by small men at what are probably uneconomic prices.

MR. R. M. CHAMBERS : Any suggestion that manufacturers do not consider their customers is entirely wrong, for this very good reason—that if a manufacturer produces a machine which does not make more profit for his customer that customer is making less profit and is less able to become a bigger and better customer.

MR. P. FINN-KELCEY : In the table at the end of the Paper the author mentions the maximum and minimum hours employed in dealing with breeding sows. Is the very high figure due to the fact the sows were out in arks and therefore the travelling time and man hours would be high, or were all the pigs comparably housed in buildings ?

MR. BRAYSHAW : There is a lot of scope for rationalising work methods in and about farm buildings, but very often better methods cannot be introduced without first altering the buildings. The present obsolete state of many farm buildings is one of the biggest difficulties in the way of more labour efficient livestock husbandry. But although mechanisation may not have the desired effect without first re-organising the buildings, I should prefer to consider this problem the other way round. It seems to me that it is essential to plan your production process first and then put a roof on it. For that reason, I would suggest that you have to decide what is the best method given the present state of technology, what machines will be used in conjunction with that best method, and only then should you decide on the form of the building which will be appropriate to these methods and that equipment. I consider the architect to be important, but in the chain of events his contribution should be second to that of the methods engineer.

I would like to thank you for treating my Paper relatively kindly.

I have been doubly pleased to take part in your proceedings this evening as an individual and as an economist among those with a particular interest in Agricultural Engineering.

Although I do not myself visualise any very drastic change in the pattern of farm mechanisation within the next few years, startling innovations have a habit of appearing out of nowhere, often as a result of the inspiration and the determination of one or a few outstanding men. Frequently these men are engineers, and whilst the economist can very often draw useful conclusions from his knowledge of the Law of Diminishing Returns, it is the engineers' privilege to delay its onset. Yours is therefore the last word.

carrier track rollers) ; imported from Britain ; current cost not known, but about £30. Requires two light oxen (or more in muddy conditions). Many have been seen, but they are on the decline. Although the solid rubber tyres have much to recommend them, the wheels are small and rather narrow for soft conditions. Furthermore, it seems wrong to ship metal for cart bodies out to Africa when local timbers have already proved themselves suitable.

The fortunes of an agricultural improvement scheme centred in Bambey in the Congo provide an excellent example of what the farm cart can achieve. After the project had been limping along for some time, it became apparent (in 1952) that because of transport difficulties the cultivation of food crops for sale was not profitable. So each cultivator was required to grow one-third acre coffee, neighbouring plots being placed close together (for easy collective supervision of some operations). In the next year, 2,500 acres of oil palms were planted, and a grass sward was established which will probably be extended under the young palms. The next stage was to introduce beef cattle and starting training some of them as work oxen. Light carts had appeared by 1954, and with the advent of transportation on the farms the whole system suddenly began to resemble mixed farming, and the growing of food crops for market was again being planned.

The Bicycle

In spite of official schemes to increase the popularity of carts, the bicycle remains the primary means of transport in tropical countries. Occasionally, trailers are used behind bicycles, but more frequently the load is carried on the machine itself. Bicycle rickshaws seldom find their way into agriculture, but they are seen occasionally, as is the monowheel. But both these devices are primarily for passenger transport.

In Malaya, estates as well as small-holders use bicycles for transporting cans of latex from individual " task " sites to the collecting ponits, where it is transferred to trailers or lorries. Ladies' bicycles are virtually unknown. The front forks of " working " bicycles are usually strengthened with an additional tube, and rear stands are often fitted, because there are few convenient " leaning " points.

In Uganda, the transportation of bales of cotton is frequently undertaken on the standard type of bicycle fitted with a strong rear carrier. The average load of approximately 70 lb. is strapped on with a piece of rubber taken from an old motor car tube. The necessity of transporting cotton from growing areas to buying centres has stimulated the imports of bicycles considerably. Although some cotton is transported by hand, many farmers prefer to pay professional cycle carriers 2/- per bag for transportation to buying centres.

It is now a common sight to see very large loads being transported on the backs of bicycles. Rigid 6 ft. beds, complete door and door frames, sheets of corrugated iron, etc., are often carried. There has been no serious attempt to amend the design of the bicycle, though it is difficult to say whether this is due to lack of initiative by importers or to extreme conservatism on the part of the users. Even in urban areas where deliveries of groceries, etc., might be feasible, there is said to be a strong resistance against the use of bicycles fitted with a large front steel carrier. In order to cope with the load adequately, it is essential that the bicycle should be large and strong, and most Africans have fixed ideas about which types are the most lasting. Stimulated by transportation of cotton, urban areas are now almost entirely supplied, with milk and vegetables transported on bicycles.

Ropeways

Another means of access to isolated sites which is worthy of special scrutiny in connection with plantation crops is the aerial ropeway. Light ropeways may also have something to commend them in some peasant-farming localities.

Aerial ropeways are, of course, in fairly common use for timber extraction and they are to be found on some tea estates. Their main advantages become evident in rough terrain. Large-capacity ropeways capable of carrying up to 300 tons per hour are expensive to install, but lighter, " temporary " equipment is coming into use. A Swiss Company, for example, has introduced an endless monocable which serves for both traction and carrying, and which can be installed temporarily—mounted where possible on the trunks of growing trees. Special hooks are provided for attaching the loads to the moving cable. A skid-mounted, diesel power-unit provides the traction, and about 20 tons per hour can be moved over a distance of about 2½ miles. Similarly, experiments have been conducted in Germany with a light alloy portable ropeway supported on alloy shearlegs.

Land Trains

Another means which has been tried of overcoming the problem of no roads is the use of " land trains." As long ago as 1932 a British engineering firm, very well known to the Institution, had placed some land trains in China, where they were to operate over what might be called, appropriately enough, roadless country. An illustration of 25 years ago shows a roadless train consisting of a track-laying tractor and three large four-wheeled trailers.

This theme was further developed into the idea of monster translandic trains of at least 200 tons capacity and capable of travelling over earth surfaces on which no expensive treatment would be necessary. And now, twenty years later, a large American company has revived the idea and has built two prototypes.

These vehicles can transport extremely heavy loads over terrain impassable to, or extremely difficult for, other types of heavy cargo carriers. Cross-country operation is said to be efficient and economical ; costs per ton-mile are claimed to be less than for normal transport over improved roads. The equipment consists mainly of two types of diesel-electric cargo-carrying machines :

1. A single unit, 6-wheel drive " 35-ton transporter," which will carry 70,000 lb. gross and is available with a

range of tyre sizes from 6 ft. ext. dia. 30 ins. wide to 10 ft. ext. dia. 48 ins. wide. The recorded pull of such a vehicle loaded with 32 tons was 57,000 lb. ; maximum speed, 15 m.p.h.

2. A " cross-country freighter " multiple car, all wheels driven, built up from standard components according to users' requirements with regard to horsepower, capacity, tyre size, load, ground pressure and climatic conditions. There are two main types available :

(*a*) 100-ton train of three 6-wheel drive cars, linked together ; the power car carries the diesel-electric generator, the control cabin and a pay load of 26 tons ; the following cars each carry 37 tons.

(*b*) 185-ton train of six 6-wheel drive cars, the power car being entirely devoted to the generation of power and the control of the train. The cars are controlled by simple electric controls, and each automatically tracks the one in front. These freighters are being used in the Arctic to supply the distant early warning radar posts ; have been reported to be at work in the South African gold fields, and in deserts and jungles for transportation. I have not been able to confirm the latter reports.

A suggestion made three years ago in Tanganyika implied the use of agricultural tractors with trains of trailers operating on narrow, cambered " trails." The trails would be of earth, graded annually as required, and would be 6 or 8 ft. wide. Trailers would be taken up or down hills one or two at a time and re-assembled into trains at top or bottom.

Tractor-trailer trains have been successful in one or two areas. One such venture operated by the Rural and Industrial Development Authority in a Malayan paddy area has proved quite profitable. The trailers are small and can be manhandled quite easily. They are suitable for narrow roads and a number of widely dispersed trailers can readily be assembled into one train for haulage to a rice milling centre.

Similar trains have been used in coconut estates in Malaya and are now being introduced on to some of the Rhodesian tobacco farms. Different tobacco farmers have different ideas about transportation, but the following is a fairly representative example of the latest system of leaf transportation.

Tobacco

Tobacco leaf is extremely valuable and a slight mistake, or a few hours' delay, in reaping and curing the crop can mean a loss to the farmer which might be measured in thousands of pounds. The latest idea is to lay out the fields so as to facilitate reaping and transport.

In one case, the reaping unit might consist of eight small trailers. Each trailer is designed to be self-balancing and readily manoevrable by hand when loaded ; six trailer loads are just sufficient to fill one curing barn at one " go." It is important that flue barns should be filled quickly and not disturbed until the curing process is complete. While four trailers (with one tractor) are at the line of flue barns being unloaded the other four are in the field. Two trailers (A and B) are pulled separately by two light tractors on field " roads " 1 and 3 (or they may be manhandled), while the other two trailers are pulled by the transporter tractor on field " road." The leaf is reaped by hand, the workers moving along the rows of plants and the field layout is such that the reaper has collected a good armful of leaf by the time he reaches the field road upon which a trailer is standing. When the four trailers are loaded they are hitched up into a train behind the transporter tractor and removed to the tying shed and barns. Meanwhile, four empty trailers should have arrived on the field. The dimensions of a small tobacco trailer might be 8 ft. by 4 ft., with 2 ft. sides, but many tobacco growers use standard trailers.

Sugar Cane

The shifting of sugar cane from field to factory probably represents the greatest single agricultural haulage problem which has to be undertaken on the grower's side of the industry. At least seven and, perhaps, as many as twelve tons of cane have to be carried to a cane sugar mill for every ton of sugar produced. Fortunately, the residual crushed stalks (bagasse) make good factory fuel, so the return transport problem is not serious.

The mechanics of transporting sugar cane from the field to the factory is focussed on a bundle of cane stalks —a vast " sheaf." Usually, the harvesting is arranged so that the canes are cut, cleaned of trash, topped and thrown on to a heap or into a vehicle. In either case, it is usual for the pile of canes to be accumulated over one or two chains (known as cane slings) which have been laid down previously on the grounds as on the deck of the primary transport vehicle. The cane bundles or entire loads can be lifted by hoists or cranes using these slings. A sling-load of cane will weigh between 1 and 3 tons, depending on cane variety, length, manner of loading, etc., and these bundles may be retained as entities throughout their journey to the factory, or they may be " tripped," at some stage, into railway wagons or other large-capacity vehicles which can be tipped at the factory intake. Rail wagons are often tipped bodily.

Sometimes, especially when the haul is not more than five miles, tractors may pull two or more trailers, each of which may carry one or more bundles, which may have been loaded by mobile hoists in the field, or winched up on to the trailer with the help of the tractor power take off. At the factory yard—where quick discharge is essential—the bundles may be unloaded from two trailers simultaneously ; empty slings are quickly placed on the trailers and the outfit may be on the move again before the load of canes has been deposited by the hoist.

For longer distances, motor trucks are rapidly replacing other modes of haulage, especially where good road systems are maintained at public expense. Articulated vehicles have a great advantage here. The bodies, which are often built specially to local requirements, should be as wide as highway regulations permit and long enough to carry four bundles of cane on the bed. A load of eight to ten bundles will usually be carried and the all-up weight of the loaded vehicle will be 15 to

25 tons, depending on the precise type of vehicle and local highway regulations.

In Commonwealth sugar cane growing areas, estates are tending to give up the old-established system of tramlines or estate railways in favour of fleets of motor vehicles which are proving to be more flexible. It has been suggested in South Africa that, although no material, direct savings in costs have been achieved by abandoning the tramline system, there has been a marked reduction in the number of labour units employed. The new methods, which allow trailers or even motor trucks actually to enter the fields, relieve labour of the most tiring task (*i.e.*, carrying and loading what has been cut during the day). The cane cutter can now cut more and earn more. One man usually cuts, detrashes and heaps three to four tons of cane per day, although exceptional men occasionally do as much as eight tons. An incidental benefit is that the cutters do a *better* job ; whereas it was previously commonplace for canes arriving at the factory to contain 10% trash, the proportion can be reduced to 4% by careful work.

To quote an extreme case of specialisation in agricultural haulage, I would like to refer to the Hutchinson Sugar Company in Hawaii, who grow 5,200 acres of cane on an exceptionally fertile mountain side, the yield being 90–150 tons of cane per acre. The haul starts at an elevation of several thousand feet and drops down to the factory located much lower. The haul route drops 2,500 ft. in three miles.

Having had experience of dump-trucks, conveyor bottom trucks, side-unloading trucks and single-axle semi-mounted trailers, the Company now uses dual-axle semi-trailers pulled by dual-drive, off-highway trucks. The power unit is a 250-h.p. supercharged diesel which maintains a practically constant performance from sea level to 12,000 ft. The trucks are fitted with torque converters, torqmatic transmissions and torqmatic brakes. These facilities reduce driver fatigue and simplify training ; there is less damage to gears, and brake life is extended to six times that of other methods of braking.

The trailers are designed to carry 25 tons, consisting in dry weather of 18 tons of cane and the balance trash and soil. In wet weather the load is heavier. Tyres of size 16 : 00 × 21 aid flotation in muddy fields, and do not pick up stones which would be liable to become caught between double wheels.

Sisal

The problem of transportation on sisal estates resembles, to some extent, the problem on sugar estates. The area of land required to produce sisal leaf for a sisal " decorticator " is 3,000–5,000 acres. The fibre content of sisal leaves is only 2·5 to 5%. One acre produces about 40,000 leaves, weighing 30 tons, each year. This bulky material has to be carried into the factory, and bulky waste has to be disposed of. Usually, flumes dispose of factory waste into a nearby valley.

Sisal leaf harvesting tasks vary, but in Tanganyika one man cuts, bundles and carries to a feeder rail line 2,100 leaves in 70 bundles of 30 leaves each. Bigger tasks could be undertaken if leaf collection and carrying could be mechanised, but no satisfactory method has been devised and put into practice. The present practice involves a labour force of 120 to 300 men per decorticator for cutting alone.

Miscellaneous Special Vehicles

Various specialised vehicles appear from time to time to play their part in agricultural transport overseas. Recent introductions, for instance, include a dual-purpose trailer, which in addition to the usual deck space has a hollow chassis which will carry 100 gallons of liquid. If the chassis is sealed full of air the trailer can be floated across water—an asset which might occasionally prove useful overseas.

The Rural and Industrial Development Authority in Malaya is operating special rice milling trailers equipped with a huller, polisher and cleaner driven by power take-off from the tractor which pulls the unit from village to village.

Specialisation of a similar kind is appearing in North America, where mixed stockfeeds are being prepared in special vehicles. A typical unit includes a hammermill, a dust collector and a molasses mixer, all mounted on a motor truck chassis or trailer. The molasses is a special feature, because the handling and mixing of molasses is usually an unpleasant and laborious job on the farm. The mobile mill may carry as much as 3,000 gallons of molasses in a heated tank so that it can be metered and applied freely even during the winter. Ideally, of course, the truck can perform the mixing operation on the site where the feed is to be consumed.

Very high wire-sided trailers are used for transporting coconuts on some plantations. The nuts are shied into the trailers, but are dumped by withdrawing a series of pins and allowing one side to swing outwards from the top. On a West Indian plantation some success has been achieved with an articulated vehicle consisting of two trailers connected with a single universal coupling at a point directly above the single coupling. The two trailers not only followed neatly round corners, but were free to adjust themselves to undulations in the ground surface and were self-supporting (in a physical sense) when detached from the tractor. There were, however, several obvious disadvantages.

Incidentally, some coconut plantations in Malaya and in British Guiana are laid out in such a way that the whole field drainage system (which consists of open trench drains) can be flushed with water from a higher level. In order to transport the coconuts from field to copra factory, all the planter has to do is to kick them into the nearest drain and flush the system. The mill must, of course, be situated near the drainage outfall, and the floating nuts are collected by a steel grill.

Summary

The object of this Paper has been to review some of the more important problems of agricultural transportation overseas, and to indicate that the solution of many

of them is not merely to design and build vehicles which will fulfil particular mechanical needs.

The controlling factors in many parts of the world are still political, economic and social. On the other hand, there are some particular applications for which special vehicles must be designed in the closest collaboration with the specialist user.

REFERENCES

FISCHER, K. H., 1957. "Farm Mechanisation in Iraq," *Trop. Agric. Trin.*, 34, 3.

BROATCH, J. D., 1957. "Agricultural Transport in Ghana," private communication.

MARCH, G. F., 1948. "Transport in the Sudan," *Agriculture in the Sudan*, Oxford.

FERGUSON, W., 1957. "Transport in Nigerian Agriculture," private communication.

Anon. "Translandic Cross-Country Train for Land Transport in Undeveloped Countries," Heavy Tractor and Carrier Co., Ltd.

Anon. "New Horizons in Off-Road Transportation," R. G. Le Tourneau, Inc.

HAYNES, D. W. M., 1957. "Agricultural Transport in Malaya," private communication.

SELBY, 1957. "Transport in African Agriculture, Nyasaland," an unpublished note.

HAYNES, D. W. M., 1954. "A Preliminary Survey of Transport Methods in Paddy Areas," *Malayan Agric. Journal*, 37, 3.

ESCHENWALD-HESS A. RIOLLANO, A., 1954. "Cane Handling in the Puerto Rican Interior," *Sugar*, 49, 8.

Anon., 1956. "Improving Methods of Cane Transportation," *Australian Sugar Journal*, 48.

CAMPBELL, J. S., ROSHER, P. "The Use of Wheeled Tractors of Medium Power for Sugar Cane Cultivation in Trinidad," *Int. Sug. Journal*, April, 1957.

BENTLEY, J. P. N. "Development in Cane Transportation and Handling in Natal," *S.A. Sugar Journal*, 40, 1956.

Anon. "Slash Your Costs of Sisal Leaf Transport," *East African Farmer and Planter*, Dec., 1956.

LOCK, G. W., 1957. "Some Aspects of Sisal Growing in East Africa," *Trop. Agric. Trin.*, 34, 3.

DISCUSSION

MR. R. H. NOCTON : Mr. Mayne has certainly given us a comprehensive survey of the transportation problems there are in various parts of Africa. I think more modern methods of transport depend largely on the economical aspects. I have found that where a commodity usually commands a good price the grower, the buyer, and incidentally the Government of the country, usually get together and find some form of transportation to suit the case. In Iraq, for instance, which has a very good road system (as good as anywhere in Africa and Asia) there are vast differences in prices of commodities. Wheat, which is grown extensively, fetches about £20 a ton to the grower. He can afford to combine it, and he can afford to transport it by conventional forms of tractor-trailer lorry and so on. Barley, on the other hand (and very poor barley, it is true), fetches around £8 a ton. The grower cannot afford to combine it ; he cannot afford to have it transported by truck or trailer. What he can afford is to have it transported out of the field by horse, donkey and women. It is then thrashed by the same method—horse, donkey, and women. The grower seldom sells any ; the landowner, who takes his share, transports it by conventional methods.

On the other hand, Iraq, as a producer of oil, gets a good price for it, and some of the largest lorries I have ever seen operate through Iraq carrying oil, which is a relatively high-priced commodity.

I do feel, therefore, that each transport problem has to be tackled on its own merits.

Then, of course, one has the bugbear of maintenance. The people of Africa and the Middle East are not, as yet, very mechanically minded. Who wants to sit on a hot tractor in a shade temperature of 130° F. ? It is much better to sit underneath a horse. Therefore, the manufacturers of trailers, tractors, lorries, etc., have to bear in mind that these implements are sometimes used under the most incredible conditions. I have in mind one particular very popular form of transport used extensively right through Africa. I still cannot understand why it is necessary to fit two different types of spring or two types of shock absorber on the same vehicle, or to place the petrol pump in such a position that it will not function at over 100° F. shade temperature. All this has been pointed out, but still it goes on.

The whole system of agriculture in these places has to be studied before any manufacturer can come out with some brilliant scheme. Take rice, for instance. In Iraq, I suppose almost all of it is transported from the field on the heads of women. Quite frankly, after studying it for some years, I cannot see any other way of doing it under their present system of agriculture. It is quite easy to say they should dry the field and wait until it is hard enough to use animal or mechanical transport, but that is not the whole story. It has to be carted within 24 hours of cutting, otherwise it sheds. The irrigation water is stopped the day cutting starts ; the reason for that is that as soon as the rice is off a crop of barley is sown. There is no more water coming from the irrigation canal on account of cost. The barley germinates from the moisture left on the land and is helped to grow by any rainfall. It will be readily seen that under this system of agriculture the more conventional methods of transport would never succeed.

MR. J. A. C. MAUGHAN : There is one aspect of this transportation in overseas agriculture which Mr. Mayne has underlined in his Paper ; that is the ever-increasing part played by trailers of many different types in tropical agriculture. Farm carts, Scotch carts, wagons and more modern types of two and four-wheel farm trailers, with and without tipping bodies, all have one basic principle in common—that they depend on an independent prime mover, four-legged or four-wheeled, to operate them.

I think this separation of prime mover and load carrier has a great significance in the development of agriculture in backward areas. The African farmer with a Scotch cart uses it behind the same oxen that he uses for cultivation and for other tasks that are beyond his own human strength. His first trailer was probably a rough sledge, which would be low in efficiency and even more detrimental to the Administration's laboriously-made roads than the steel-wheeled cart.

Moving on from that, his next step, still using oxen, would be to replace the steel-wheeled cart with a pneumatic-tyred cart. This, not unnaturally, very often receives encouragement and financial subsidies from the

Government concerned in order to keep their wear and tear of roads down, if nothing else. But at this point, if the African farmer is a fortunate one and is ready for further development (I use him as typical), he reaches the point of mechanisation. Maybe he will take part in a co-operative scheme, in which case a tractor and some of the necessary transport will come from the common pool, and sooner or later, if he needs his own tractor, he will want to hitch his own transport on to the tractor available.

Mr. Mayne made reference to the haulage of sugar cane in the fields. The conventional vehicle for that is the 5-ton four-wheel trailer of a specially rigid, robust construction, large wheels at the back and small 16 in. wheels on the front, with a universal unit pivot point. They were developed in the first instance by the Americans for their own cane fields, and subsequently adopted as standard.

There are some markets, notably Trinidad and Brazil, where they have shown preference for a two-wheel version of that, because of local conditions and local prejudice. There are complications in operating trains of two-wheel trailers, but they seem to overcome the difficulties, in that case, at least.

Very briefly, the advantages of a four-wheel trailer can be summed up as follows : It will stand four-square on its own wheels and remain mobile ; it can be hitched with a minimum of trouble to almost any tractor ; the height of the draw-bar is desirable to be kept to the same height, but you *can* pull the trailer with a tractor of a markedly different draw-bar height. By and large, the four-wheel trailer is much easier to couple up into trains, provided you have a reasonable amount of room to allow for cutting in on corners.

The turntable type of four-wheel trailer has some disadvantages, in that it is not usually a rigid construction and loses some stability at 90° angle of turn. This limitation is being overcome by the use of car-type steering, which, although in the early stages it went through a difficult period and mistakes were made in the earlier designs, and the construction got itself a bad name due to limited lock and weird and wonderful tracking of wheels at sharp angles of turn, now shows that the modern design of car-type trailer, 3 or 5 tons, will provide nearly a right-angle turn quite well, also give correct wheel alignment at all angles of turn, and can now avoid the pitfall of weaving, particularly at high speeds.

For the operation of trains, two-wheel trailers can be used, but they do present more problems of stability. The design factor is more critical, generally speaking, because of the transfer of weight fore and aft from one trailer to the next, and, broadly speaking, the train of two-wheel trailers is difficult to uncouple from its prime mover.

It does seem that tropical agriculture has a wonderful opportunity here in its development of short-circuiting a lot of the trial and error problems that beset the older countries. Each application of trailer transport wants its own intensive study, but these basic factors do remain, and can be assessed very often before the more detailed problems are discussed. The problems of distance, terrain, unit loads, motive units available, all have a bearing on the ultimate design of the trailer, but the basic factors can be taken into consideration beforehand.

MR. R. CHAMBERS : I read a number of agricultural journals, and in one was the statement that the population of the world is increasing by 2·5% per year ; another statement was to the effect that F.A.O. reported there were more asses than ever in the world.

I now begin to realise that more asses are needed for transport. It strikes me, in any calculations that are being made about mechanical transport, the people who breed asses seem to think that asses cost nothing.

I wonder if Mr. Mayne can give us some idea of the stock value of the six animals—in this case bullocks—which would be pulling the cart he mentioned.

Can Mr. Mayne give an idea of the method used for timber extraction ? Surely that is one of the important products of many of our overseas territories ?

A third point : Approximately what percentage of the work of the farm is transport ? In the United Kingdom, transport with tractors and trailers can be up to 40% of the farm's work. Perhaps Mr. Mayne can say it is as high as that in the areas to which he has referred.

MR. MAYNE : Those are three difficult questions.

As to the value of the bullocks, I do not know ; it is not quite so simple as that. They might be bound up with the tribal way of life or something like that. If they are simply kept as bullocks on the farm, I suppose their value, according to how close they are to a meat market and what sort of bullocks they are, would vary from £8 to £40 each.

Methods of timber extraction : I feel Mr. Maughan is more knowledgable about that than I am. The methods of timber extraction, generally speaking, are technically and economically far in advance of methods of agricultural transport, because it is more an industrialised type of operation, especially when the timber is of export quality.

The main vehicles of extraction are articulated types of timber-hauling vehicles such as one sees in this country. In some cases, very much larger vehicles are used, rather on the lines of the 25-ton type of thing I mentioned in connection with sugar cane, on some highly mechanised estates.

As to the percentage of farm work spent on transport, it would be lower than in this country, but in general the amount of time coming and going from home to field and moving produce about, taking little bits to dry and prepare and process, would be very much higher. Transport in and about the fields would be less.

MR. R. H. NOCTON : For what it is worth, I do know that African elephants are used for moving timber in the Belgian Congo. The firm holding a timber concession on Mount Kilamanjaro in Tanganyika did consider bringing elephants from Burma, but I don't think this was done ; very large timber carrying equipment is used.

It was necessary, of course, to spend a good deal of money on road construction before this mechanical hauling equipment could be used.

MR. R. M. CHAMBERS : In Ceylon, when I was there in 1952, agricultural tractors and trailers were displacing 3-ton lorries for the carriage of tea leaf to the factory, and in cases or chests from the factory to the railhead. That was mainly due to the greater manoevreability of the tractor-trailer combination for negotiating sharp corners and narrow roads in Ceylon.

MR. P. FINN-KELCEY : Can Mr. Mayne give any reason, historical or otherwise, as to why trailers are so high off the ground ? Is it a remnant of the days of four-wheeled waggons with the turntable underneath ?

In this country, when loading sacks of potatoes which have been picked up in the field, we still insist on having the trailer high. I saw recently a very low ex-R.A.F. bomb trailer, about 12 ins. off the ground, with wide load-bearing pneumatic tyres which I was assured was carrying 3 tons of potatoes.

If a heavy load-bearing trailer can be made for rough ground, why do we have to lift everything up to these great heights ?

MR. MAYNE : As to why a trailer is so high, this inconvenient feature must be accepted because it is necessary to get the deck above relatively large-diameter wheels in order to get the maximum loading width within Highway Regulations.

One finds low-loading trailers on some sugar estates, as I mentioned in the Paper. There the large-diameter wheel necessary for crossing pretty rough ground is outside the load, so you get narrow trailer body and the wheels outside.

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CONFERENCE ON SOILS AND CULTIVATIONS

The following Papers were presented at a Conference organised the by East Anglian Centre of the Institution held on 12th February, 1958. In addition, DR. P. C. J. PAYNE *read a Paper on The Nature of Soil Workability, based on a similar Paper read in London in 1956 and published in the* JOURNAL, VOL. XII, NO. 4.

THE PHYSICAL PROPERTIES OF SOILS

by DR. N. H. PIZER*

This Paper was illustrated by a number of Slides which limited space does not permit inclusion in the JOURNAL. *The accompanying wording is however included as it may be of interest.*

I THINK there is much more interest today in the physical conditions of soil and the effect of these conditions on the growth of crops. To us in the Advisory Service, soil conditions seem at times to be quite dominant in the way a crop grows. Often the nutritional side, as far as anybody can see, is quite sound, but the crop is not growing as well as it should. In many cases we find that there appear to be physical defects in the soil. Now what those defects are seem to vary from one soil to another, and I do not think anybody can generalise. One has got to take the soil that you find, study what you find there and try and work out how the condition arose—whether it is one that is inherent in the soil, whether it is one that can be remedied, and also whether it is affected by cultivations or by season. As you might suppose, there is a lot of " guess " goes into it. We try where we can to confirm our guesses, and I think mostly we are right. I think I can sum up the key to it—you should be able to find a section through soil and subsoil that there is unhindered root run and certainly no layers that are likely to restrict root development ; also the kind of tilth produced should be stable to normal weather conditions, and—a thing that the Chairman did not mention—that drainage should be good. Now, he also mentioned Mrs. Beeton, and I will add to his remarks on that. You can start off with the same ingredients and two people can get very different results, and that is perfectly true of soils. The art of cultivating soils is just as important as the inherent property of soils. In going around, one sees difficult soils being reasonably well managed, and very often elsewhere they have got into a bad state. I am going to show you slides of soil sections which we have examined in the field, show you some of the faults and good points of them, and discuss with you how those soils might change. I think that will be far more useful than just talking generally about such matters as tilth and soil structure and soil organic matter.

I know you come from a very wide area, and it is quite possible that some of the soils I have to show you are of little interest to you, but it does happen that I have a wide range of soil types and I think there will be something that will be of direct interest to you. I don't want to talk any more generally—I think the next move is to have the slides and look at different soil conditions. I do not pretend we have found all of them—I am sure there are lots of variations—but if I can I will give you an idea of what might be found and how one might deal with it.

Slide. Soil map of East Anglia. Eastern Region—put on to give an idea of the range of soil conditions that might be met with in this area. Dark areas of clay—Huntingdon, Herts. and Suffolk. Strip running across through Suffolk and parts of Cambridge and Essex. These clays differ in physical properties. The main difference is that some of them have never been compressed. Essex clays are more difficult to deal with than Suffolk and Huntingdon clays. Along the east coast is an area of light, sandy loam. Central area of Norfolk and Suffolk are mixtures of soils which vary from loam to sandy clay loam. Sandy clay loam is a very tricky soil to handle. In East Norfolk are some of the best loams in the country. Problems arise from intensive arable farming on most soils. In the West of the County of Norfolk sandy loams of very open texture. In the area round the Wash are peats and silts which have an infinite range of properties.

Slide. Map showing Southern England and the need for irrigation. In the black area on the east side in nine years out of ten there are drought conditions. Included in this area is an area in centre of Norfolk which has a slightly better record. After that, as you go west, drought conditions are less frequent. In Eastern Region are areas of soils low in organic matter. The reason is a simple one—root development is restricted in the dry times. Similarly, the warmth of soil is greater in the early part of the year and throughout the summer, and breakdown of organic matter is much more rapid. In consequence, it is most difficult to increase organic matter on the east side, where droughts are frequent and soil temperatures high.

Slide. Section through chalky soil. Loamy soil overlying a subsoil of chalk mixture. Note hard and soft chalk pieces. Size of chalk particles affects its properties. A difficult soil to handle. Amount of drought depends on the amount of hard chalk in the particles. Fine-grain chalk is unstable to weather. If this is brought up to the surface by deep ploughing it is very difficult to handle in the Spring and caps badly in rain. If the top subsoil consists of a fine-grain chalk it is so difficult to handle that deep ploughing should be avoided.

* *National Agricultural Advisory Service.*

Slide. A chalky soil. Has been deep ploughed, showing fine-grain materials which have silty properties brought to the surface. Sugar beet is very sensitive to coil conditions in chalky soil. Remedy—to avoid cultivations as much as possible and grow crops that do not need continual cultivations and which restore humus to the soil.

Slide. Section through soil showing layer of fine-grained soil overlying chalk. The mixture is unstable to weather. It can easily be worked into a tilth, but this is as easily destroyed by rain. To keep in good order, it really needs a fair proportion of organic matter. Note a tight layer well below the surface which is caused by ploughing at constant depth, particularly by constant ploughing with a smooth bottom to the furrow. The bottom of the furrow during ploughing in wet period is liable to form a " smear," which seems to prevent water going through this area and so seals off the bottom layers of the soil from the subsoil. Deep ploughing under these conditions is a great benefit because it causes the " smear " layer to be mixed with the top soil, where it really belongs and from where it has been washed down. If this type of soil is cultivated a lot, it tends to lose its structural stability and at the same time the soil fertility deteriorates. This soil is very akin to brick earth.

Slide. Section through a soil and subsoil which is like Norfolk loams and brick earths. Fine-grained material, very little coarse sand. This is potentially a first-class soil because it has potentialities for extensive root run. The subsoil fissures readily so that roots can find their way down very easily and plants can become deep rooted. Here, too, it is possible to form a plough pan. In slide, the field is shown down to grass to restore fertility. Plough pan can be destroyed by deep ploughing, but this has the effect of diluting organic matter in top soil. Subsoiling is preferable in these conditions in order not to dilute the top soil. Responds very readily to ley farming to restore fertility and soil texture. Often these soils may look to have bad structure, but it is unnecessary to resort to ley farming while cropping yields are maintained. Often these soils have iron oxide cement in them.

Slide. Showing sugar beet crop on sandy clay loam field. Sand and clay were originally put down in layers, but have become mixed as a result of cultivations. The amount of clay is small in proportion to sand and is unable to bind it together. These soils give great crop variations according to their physical condition—that is, the proportions of sand and clay in the mixture.

Slide. Showing effect of rain on surface of clay loam soil growing sugar beet, showing some cracking. These soils pack down very tightly, preventing air supply to plant roots. Fine tilths on these soils should be avoided. If packing happens there is a need of implements that will break up the top soil again without damaging sugar beet crop.

Slide. Some soils respond very quickly to compression of the surface. Often the damage affected by this is more the result of " smearing " the surface than actual compression. Headlands are most affected by this by the turning of the tractor under wet conditions. Light surface cultivation under dry conditions will often remedy matters.

Slide. Crop of sugar beet in distress. Effect of salt on these soils in a wet season is to make tilth very unstable. Unless the salt is very evenly distributed, the resulting crop is liable to be very patchy owing to breakdown of surface tilth where the salt is applied heavily. In consequence, it is very important to plough in salt after it is applied.

Slide. A section of heavy boulder clay soil well fissured into subsoil. " Boulder clays " generally vary from light sandy loam to heavy clay. This slide shows heavy clay sample. Often a layer of very heavy texture at about 2 ft. below the surface. Speaker suggests this is caused by fact that clay material from the surface is washed down fissures after a dry summer. These cracks often extend to about 2 ft. deep. Suggests this layer of fine material should be broken when the soil is dry by a tool like a mole plough at varying widths. Some fields need to be broken every yard, some every two yards.

These types of soil are liable to get into blocks if deep ploughing is done under very wet conditions. Blocks are liable to form several inches below the surface where frost and weather conditions do not reach them. Plant roots cannot enter these blocks of soil. Deep roots of lucerne penetrating into the subsoil have much better mechanical effects of restoring soil structure than grass roots which are confined to the surface of the soil.

Slide. Shows heavy boulder clay which was ploughed rough and subjected to frost, showing shattering of the soil lumps by frost. Important on this soil not to cultivate subsequent to frost when soil is wet.

Slide. View of crop of mustard drilled on wheat stubble in autumn of 1956. Mustard is very susceptible to soil conditions. Heavy rain followed sowing of mustard. Surface of soil covered by a " slurry," which caused a total crop failure over large areas of field.

Slide. View of rotovator at work on seed bed. Danger of packing soil below the tilth formed by the implements. This pan condition can be remedied by putting a tined implement through the soil after the rotovating is finished. The same conditions and remedy occur after discing.

Slide. View of rotovator working in heavy soil. Batterings of the rotovator breaks up soil pumps, which is not the same as action by frost and detrimental to tilth. Speaker advised that a period for normal weathering should be allowed before completing seed bed.

Slide. Soil in river valley, where subsoil water is constantly moving and in consequence leaches the subsoil. Important here to lower the level of the water, but very difficult to restore the physical condition of the soil after such drainage. The lower layers of subsoil in this class of soil are not worth bringing to the top by very deep ploughing.

TOOLS AND TILTH

by J. C. HAWKINS,* B.Sc., N.D.A.

ANY discussion on cultivations must start with autumn ploughing, because so many spring cultivation troubles, especially when there has been little or no frost during the winter, are made in the autumn.

There seems to be only one reason why the mouldboard plough is still the basic tillage tool in Britain. Practically anything that it does can be done more cheaply by other implements. Cultivators, rotary cultivators and disc implements will all break up and aerate soil, mix in fertilisers and organic matter, open up the land for drainage and get rid of the residue of previous crops, but only the mouldboard plough will bury. That means that it is more effective in killing weeds in the British climate than the other implements. That, too, is why it always has been and is likely to remain the basic tillage tool in temperate climates where weeds are not killed in a few hours by hot sun when soil is just loosened. Many experiments have been done on his all over the world and the results are nearly always the same—fewest weeds appear after mouldboard ploughing and most weeds after rotary cultivation, with disc ploughing somewhere in between.

If the chief virtue of mouldboard ploughing lies in its weed-killing powers, then it is common sense to use and set ploughs so that they do this as effectively as possible. In other words, it is worth taking trouble to see that everything on the surface is buried under as much soil as possible, with no gaps for weeds to grow through. First of all, no plough should be used without efficient skim coulters if the ploughed surface is to be worked down into a seedbed. Then a wide enough furrow width should be chosen so that the furrow slice is turned and placed properly at the depth chosen. Depth itself is relatively less important, as has been shown by recent deep ploughing experiments in England. About the only consistent result of deeper ploughing has been cleaner land, and this has probably been due to more complete burial of weeds and the placing of more soil on top of them.

The way ploughing is done is not, however, the whole story in weed control. When it is done can be just as important. Early ploughing in the autumn has long been considered to be good practice, but this is by no means always true. Part of a field, for example, ploughed out of barley stubble on the 6th September this year with skim coulters on a well-set plough has been green by the end of October, while the remainder ploughed at the same depth by the same plough set in exactly the same way on the 23rd October has been clean at the end of January. The reason for this is that weeds, seeds and shed grain were buried by the earlier ploughing when the ground was still warm enough for growth and they grew through the furrows. With the later ploughing they had germinated and grown on the surface and were killed by burial. It could be, therefore, that the virtues of early ploughing belong to the horse era, when, if you did not start early, you did not get it done. Today with tractor power it may well pay to be rather over-equipped for ploughing to carry out some stubble cleaning and delay the start—at any rate, on land which will carry tractors later in the year. The hard weather, which has most effect on the furrows, very rarely comes much before the end of the year.

Against the virtues of later ploughing for weed control must be balanced the virtues of early ploughing in a winter with little or no frost. Late ploughing then on heavy land can give smeared, unbroken furrows, which become a problem in the spring. Late root harvesting, too, may add to the ill-effects of late ploughing on such land. On balance, then, there seems to be a clear case for delaying ploughing on medium and light land, although on heavy land there is a risk that, if the winter is like that of 1956-57, spring cultivations may be made even more difficult.

Late ploughing, especially on heavy land, may bring its own problem of scouring with some plough bodies. A plough fails to scour when the soil/metal friction on the mouldboard becomes so high that the furrow slice is not strong enough to provide the force to overcome it, or, to use more precise terms, cohesion plus the apparent internal friction of the soil is less than the adhesion plus the soil/metal friction. The high value of soil/metal friction under non-scouring conditions is probably due to a high normal load on the mouldboard caused by moisture tension over the critical range of moisture content. This is supported by the fact that if a soil is wetter, and hence its moisture tension is lower, the plough will scour. Further, if it is drier, the moisture film on the mouldboard ceases to be continuous until, in spite of the higher tension at the lower moisture content, the normal load on the mouldboard falls off and the body again scours.

If this is the mechanism of non-scouring in mouldboard ploughs, then there is a limited number of things which can be done to overcome it. Any form of consolidation of the soil will help, of course, by increasing its strength and hence the load it can sustain to overcome the soil/metal friction on the mouldboard. Conversely, non-scouring is common in cross-ploughing, when the soil is looser. As to the body itself, it is unlikely that any new materials with low friction properties will show advantages over a hard steel surface unless they hold their polish as well. The mouldboard shape may have an effect depending on soil properties. Usually, a gentle body like a general purpose will scour more readily than

* *National Institute of Agricultural Engineering.*

an abrupt one like a digger because it imposes a lower normal load on the soil and so reduces friction.

The mechanism which holds soil to mouldboards is probably very similar to that which holds soil to sugar beet at harvest time. Apart from the binding effect of rootlets, it seems likely that the moisture tension is largely responsible for holding the soil to the surface of the roots. This is borne out by the fact that, over a range of moisture contents on most heavy soils, no amount of mechanical treatment will clean beet beyond a certain point. It is necessary for the soil to dry and shrink so that the bond between it and the roots is weakened before further treatment will clean them.

Apart from weed control, ploughing can be done so that it makes subsequent cultivations easier or more difficult and can go some way towards counteracting the effects of an unfavourable winter. Broken work is to be preferred to set up. It is often said that the set up furrows will dry out more quickly in the spring and so permit earlier cultivations. This is often true on the surface, but underneath it is usually so wet that the weight of tractors and implements can do untold harm and, as every tined cultivation brings some soil from below to the surface, the tilth itself mav be affected. Broken work is produced by using the right body at the right speed under the right soil conditions. It is true that shorter, more abrupt bodies tend to give more broken work than the longer gentle ones, but speed has a much greater effect.

Higher ploughing speed is an advantage with light penumatic-tyred wheel tractors. Because drawbar horsepower depends on speed as well as pull, it provides a good way of using their power without heavy ballast or the risk of losses through wheel slip. There is at present a practical limit to speed, however, except on the lightest soils imposed by the bodies in current use. Few if any have been designed for speeds higher than about 2½-m.p.h., so that, if full advantage is to be taken of the potential ploughing output of modern wheel tractors, new plough body shapes will have to be developed to produce satisfactory ploughing, from the weed control point of view, at the higher speeds. Such shapes are likely to be built up from more gentle curves than those of bodies used at present and are unlikely to be the very short, abrupt bodies developed for " speed ploughing " in the United States. Any increase in ploughing speeds will, of course, demand more efficient safety devices in the ploughs themselves.

Faster ploughing with lighter tractors is quoted as the way to reduce the ill-effects resulting from soil consolidation brought about by the heavy wheel tractors. On some soils under some conditions this may be true, but it must be remembered that the ill-effects are often not due to pure consolidation. It is very difficult to detect any significant change in soil density, even after it has been run over several times with a heavily-weighted tractor, unless the moisture content happens to be exactly right. Yet over a wide range of conditions it is possible to see a reduction in the crop behind tractor wheels. It seems almost certain that this is due to a puddling and sealing of the surface by the wheel, giving poor drainage and aeration, rather than to consolidation. If this is so, then the most serious damage is likely to occur in the furrow bottom when ploughing, but it can easily be put right by a tine mounted behind each body and set to run two or three inches deep.

Apart from ploughing in the autumn in a way that will help spring cultivations, a certain amount can be done by wise choice and use of implement to produce a seed bed in the spring, even if the winter weather has not been very helpful. Soil aggregates are weakened or broken down in nature by frost and by wetting and drying. Good cultivation, then, is an act which blends weathering and cultivation, the object being to produce a good tilth with the minimum of effort. If autumn ploughing has been done well, winter frost has broken down the surface and the weather is good in the spring, there is no problem. It is simply a matter of stroking the surface with almost anything—and sometimes nothing—and cereals or crops like peas can be drilled.

Root crops will need, perhaps, more cultivation, but not much more. The level surface needed for modern precision drilling, down-the-row thinning and inter-row hoeing should have been formed—at any rate, in embryo—in the autumn. It is wrong to go over seed-beds over and over again in the spring, when the soil is moist underneath and dry on top, in order to get them fine and level. On many soils the resulting consolidation can reduce the degree of aeration and a plentiful oxygen supply has been shown to be essential for good germination by recent work carried out at Nottingham University. Further, every tined cultivation must be shallow or it will bring some of the lower unweathered soil to the surface, which has to be weathered down by wetting and drying, and so time is lost. Such shallow spring cultivation is possible only if the ploughing has been right. If it has been polished and set up, hollows will remain under the furrow slices and the crop will suffer in the early stages. If the work has been broken the few voids remaining after the winter will be filled by the shallow spring cultivations.

Potatoes have long been regarded as a crop that can be planted in a rough tilth. This may be true with hand lifting, but it is almost certainly not true when harvesters are used. There is evidence that many clods in the seed bed will persist in the ridges until harvest and so add to the most difficult separation problem on harvesters—that of separating clods from potatoes. In Holland, for example, there is a marked tendency to attempt to eliminate clods at planting time and to carry out inter-row cultivations and spraying only when the tractor and implement wheels will not form clods. Many farmers, too, adopt skeleton wheels for their tractors on inter-row work, as they form fewer clods than pneumatic tyres. The standard British ridging body is probably quite the wrong type to use when the crop is to be lifted by a complete harvester. It is designed to put up the highest possible ridge on the narrow row widths used in Britain and to make it stable by compacting and smearing the sides ; this almost certainly forms clods on most soils. It is worth considering, as an alternative, the American lister type of body, which builds a ridge without such compression and smearing, although wider row widths may be needed if the ridges are to be large enough to avoid greening of the potatoes. The draught of this body is also often lower than that of the British one, especially in firm land.

Peas are a crop which shows a marked preference for the type of tilth produced quickly and easily by little or no cultivation on a clean, weathered surface resulting from good autumn ploughing. The desirable early drilling can often be done straight into the weathered furrows with a set of harrows behind the drill to complete the cultivation. The large seed can tolerate rather a rough tilth by root-growing standards, provided there is moisture in the seed-bed. The risk of damage from consolidation by tractor wheels so early in the year is not serious. The wheel track and row width can be arranged so that no row is planted in the area affected by the tractor wheels ; it is even possible to arrange for two wider rows to take the wheels both in drilling and in subsequent inter-row cultivations and spraying.

Although quite a simple combination of cultivation and weathering can produce suitable seed-beds after good ploughing exposed to a normal winter, the problem becomes more difficult when there has been little or no winter frost. Cultivation must then be helped by the natural soil breakdown produced by wetting and drying —the land dries, is cultivated to encourage breakdown, is left to become wet and dry enough for further cultivation, and so on until a seed-bed is reached. If the spring is wet after an open winter there is, however, little that one can do. Attempts to go on to the land with tractors when it is too wet will make the situation ten times worse, and all the farmer can do is to insure against such a spring by seeing that the field drainage is in order and that there are no artificial pans to reduce its effects.

A dry spring after an open winter, such as occurred in Britain in 1957, presents a different set of problems. Good autumn ploughing will help a good deal, but it is still impossible to make use of the technique of combining cultivation with wetting and drying to break soil down. Under such conditions, a tilth must be produced, as far as is possible, by the action of implements only. Tined implements break clods by shattering them along natural planes of weakness. Disc implements frequently have the same effect, but they can also split clods by an extremely high local load over the small area of contact of the edge of the discs. That is, they have a " cutting " action. To break clods in either of these ways the tines or discs must have something to work against. It is, in fact, the bulk of the soil which has to provide this resistance, and if it cannot do so cultivation is useless.

When the soil is very dry and loose, some clods can be broken down if they are struck by something moving so fast that they do not have time to move aside. Here the rotary cultivator may, by sheer speed, hammer out a tilth, but it may not be the ideal one and will certainly cost more to produce than if it had come more naturally from the action of the weather, helped by well-timed cultivations. One further principle which may not be fully understood is that the resistance that the main bulk of the soil can offer to a clod, and hence the chance of shattering it, are greater if the load is applied nearly vertically instead of horizontally. This accounts for the occasions when a roll or scrubber is a more effective clod breaker than tined implements.

Finally, it will be clear that there is everything to be said for doing cultivations when they will do most good and everything against attempting them when they will do no good or even harm. This means that it will often pay to equip a farm lavishly with tractor power and cultivating implements, especially on heavy soils, and to put in the maximum number of working hours with them when conditions are right.

DISCUSSION

MR. J. H. COCK : In anticipation of this Conference, several of our members have formed themselves into three groups in various parts of Norfolk to discuss cultivations generally, and particularly some of the problems of last season, but in view of the very stimulating Papers we have had, and the tremendous scope for discussion which must arise from them, I propose instead of giving you a complete summary of those discussions to pick out the main points which have a direct bearing on the Papers which we have heard today.

First of all, we come to the basic cultivation of ploughing. Mr. Hawkins implied that our outlook on ploughing was still dogged by the slow-moving period of the horse plough and there had not been sufficient progress to meet modern requirements. On our heavy soils, which I suppose Dr. Pizer would say were some of the awkward sandy clay loams and clay loams, ploughing is still one of our major difficulties, both as a cleaning operation and as a means of laying the furrow decently to reduce the spring work to an absolute minimum instead of having to level out a good deal of the unsatisfactory work which we are now getting.

Now as to the types of plough we have been using. Inevitably, we have gone deeper in recent years, but the tendency has been to reverse this tendency, and a moderate depth is now more in favour rather than extreme depth, but even so with any type of plough which is available to us we are not completely satisfied with the standard of work. From Mr. Hawkins' remarks I gather that there is still room for a tremendous amount of research work and development in the basic type of plough, and I wonder if we, as farmers, are pressing sufficiently hard for the necessary research work to go forward so that our ploughing is raised to the requisite standard.

Turning to some of the desperate remedies of last year, those of us who met in our particular mid-Norfolk group still regard the crawler tractor, where it is available, as the best possible means of handling equipment for spring cultivations. With pitch pole harrows and so on that is more or less a standard procedure. But the disc is still in use, I think, with a good deal of trepidation, and each year we are half-determined to scrap them, or certainly not repair them, but yet they still keep going, and after Dr. Pizer's photographs this morning of the harm that can be done with them, I feel that we must regard them as potentially dangerous weapons if misused or used without adequate breaking up of that hard surface underneath. Their main function, as far as we are concerned, I think, is for autumn cultivation for wheat, rather than for work in the spring.

Some of my neighbours managed to get a seed-bed of a sort by using rotary cultivators last spring, but I have discarded them entirely for seed-bed preparation. They have been, and still are, in use to a limited extent for autumn stubble cleaning, but the rate of working is slow, although the breaking up of the soil is very complete once they have gone over.

Dr. Payne mentioned that the consolidation effect of tractor wheels was very, very slight. So I think I shall have to turn to Dr. Pizer for a little more enlightenment on the harmful effects that can follow. Using Dr. Payne's figures, the compression effect of tractor wheels is five times as much as a roll, and yet how many times do we get into a field and say " Don't take a roll on to the field," but yet send a tractor two or three times more through with some sort of equipment following it. I feel that a good deal of the after-sowing effects of tractor wheel consolidation is due to the breaking down of the very fine tilth, which we want to avoid ; then after rain a complete collapse of the tilth, and consequently in some cases soil like concrete. The modern tendency for all implements to be mounted means that every time you want to do something more to the land away goes a tractor with one particular tool behind it. There is a good deal to be said for the earlier process of mechanisation when we " ganged up " behind a tractor a series of implements so that one stroke of the tractor wheels did a very nearly complete operation.

One other factor—Dr. Pizer showed some of the effects of layers in the soil caused, particularly on our heavy land, by some adverse condition. I would like to ask him to comment on the after-effects of beet harvesting where several square feet of the soil now gets the smear effect from two tractors, one pulling the harvesting machine and trailer alongside with anything up to 3 or 4 tons of beet on it. If that is late in the season there is no chance to break up the soil with a cultivator and let the moisture or water standing on the surface through. When we plough we put this stuff that has been puddled at the bottom of a furrow and turn up something that is quite reasonable underneath, but have we in fact just disguised the underneath effects and shall we have something there which will take more than one year to mellow down and come back to a decent structure ?

DR. PIZER : I think the main effects of compression by tractor wheels have been when they have gone over the soil which is a bit soft due to being moist. Certainly last summer we saw a lot of injury in crops like lucerne, due to the effect of rubber tyres smearing the soil, and I would say, also compressing it. In the case we looked at, the lucerne had been killed by this effect and you had to get in, I should say, an inch or two into that soil before you got into something that had a reasonable tilth. So when one is thinking of compression by tractor wheels the moisture state of the soil must be very clearly stated.

Then there are the secondary effects ; it does seem that once you have got a state of smear or compression in a soil the condition can get worse. Usually, it is a result of rain, but if there is a dry period following the compression the layer may dry out and then, with the following wetting, break up naturally, but if that doesn't happen, then I think the effect of running over with a tractor wheel can be increased, simply due to the breakdown of the soil, an increase in the amount of slurry formation, and the slurry going down and filling up the hollows below.

Now about the effect of beet harvesting machinery. Is there any need to plough a field that has had sugar beet on it ? If you get a soil into a bad state why not leave it until the following spring ? The damage is on top. Why not leave it until the soil dries out a bit and simply use some sort of a cultivator to break through the hard layers ?

DR. PAYNE : I think I possibly created a false impression on the question of tractor wheel marks causing compaction. The reference I made to its not being serious in the way of increasing density was as a result of some experiments we made in trying to find the most extreme conditions of rolling, and, in fact, we gave a number of passes up to 10, I think, with a fully ballasted tractor wheel running in the bottom of the furrow. We came to the conclusion that the increase in compaction as measured by change in density in the soil was not serious—in fact, 10% was the worst we got.

We did find that the " smearing " effect was quite serious, and I should like to correct any mis-impression I may have given.

With regard to the ganging-up implements, we have done a certain amount of work on that, and if you are after compaction, especially under dryish conditions with tined implements, then they are very good. You get diminishing returns ,of course, from your second set and third set, but still you do get a useful effect generally from the second tandem set. If you are after clod breaking, the chances are you will get little effect from the second and none from the third with the same implements.

MR. R. A. CLEGG : I think one of the most disappointing things that have happened to our ploughs has been the adoption of the three-piont linkage. It would be a very good thing if manufacturers would give us back some of the space they have saved by doing away with the drawbar and hake, and giving us a few more inches between our furrows. I have seen a plough which has been altered by having the bodies put three or four inches further apart, and it is very surprising what a good effect it has on the work of the machine.

I would be very interested to find out whether the effect of wheel marks is the actual contact of the wheel with the surface of the soil or whether it is the amount of weight put on by the wheel. For instance, if you are using twin instead of single wheels, you are putting half the weight on each wheel, but I don't think it has been proved, or investigated even, whether a twin wheel on heavier types of soil does just as much harm as a single. Mr. Hawkins mentioned that it is not always a disadvantage to have wheel marks in the crop. Sometimes the crop appears to be better in the wheel mark than elsewhere. I think I can explain that, especially where broadcast distributors of the spinner type are used. I found with deepish wheel marks the scattering effect of the manure tended to lodge in the wheel marks, and consequently you got better effect due, in my opinion, to getting a double dose of manure.

This year I think one of the most outstanding contributions to the economy in cultivations has been the spring tined harrow. Last year, under very light conditions, I had one drill working and two tractors with a cultivator behind each one with harrows behind the cultivator, and they had a full-time job keeping the drill at work. This year two corn drills were working with one spring tined harrow, and that man was doing four times as much work as last year.

MR. HAWKINS : The first point to comment on is more room in mounted ploughs. I agree, and that was the policy I had in mind when I suggested, with modern rubber-tyred tractors, one gear higher and one furrow less. The limit at the moment to the room you can give in a mounted plough is governed by so much weight so far back, and consequently light weight on the front wheels. If you drop off a furrow, then there is no earthly reason why you cannot give all the room in the world. Under some conditions I admit that it is worth it.

As to my comment that better crops are sometimes seen behind the wheel marks (in the case I have in mind it was not fertiliser effect), it referred to a rather woolly old ploughed out ley where ploughing had been done in traditional fashion. In fact, this was a man setting his plough for a ploughing match. He did some excellent work on the side of a hill, and when it came to being drilled and the corn came up it came up best in the wheel marks, because they were the only parts of the whole field where the hollows under the furrows got filled up.

I must say one other thing about damage by wheel marks ; where you are going over a growing crop, top dressing, rolling, harrowing, or anything else, it pays time and time again to underload your tractor, because the slightest amount of wheel slip will give such mechanical damage to your plants that you will lose them very easily. A tractor wheel slipping very slightly is one of the most potent of weed killers.

With regard to twin wheels, if we are right and agree upon surface smearing trouble—and remember, the heavier and wetter the land the more likely you are to get it—then I don't think you need a very heavy load on the surface being puddled, and I would expect a fairly lightly-loaded wheel would give a smearing effect, particularly if it slipped. On a light, dry, easy-working soil there is not much danger of smearing or puddling anyway, but at the other extreme—wet and sticky, where the soil puddles very easily—twin wheels, however lightly loaded, would probably be enough to produce damage.

MR. R. C. SHERAR : May I ask Mr. Hawkins if there is not a certain amount of damage from the lugs of the tractor wheel compressing sidways as they travel ?

MR. HAWKINS : You do get these compressed lumps of soil behind a lug and that is probably one of the sources of clods in inter-row cultivation of potatoes when it is wet, but I do not think those individually consolidated lumps, perhaps dissociated from the soil itself, are quite so serious if they are actually sheared off as a general puddling effect over the whole area.

MR. R. G. JOICE : Would the speakers advocate drilling with an ordinary coulter as opposed to a disc coulter ?

Bearing in mind Mr. Clegg's remark about double manure in the wheel marks when using a very big drill, you do get a very deep wheel mark,, and you have to cultivate deeply to get rid of it when sowing your sugar beet, thereby losing a certain amount of your top soil. Would the speakers advocate for that reason alone discounting any beneficial effect from the placing of the fertiliser in the use of placement fertiliser drills for drilling roots ?

MR. HAWKINS : I would try and avoid a disc drill, particularly on stony soils. That is a personal opinion, because I have seen too much seed left on the surface in these conditions. If, however, you are of the type of farmer who insists on ploughing in a good crop of straw, you can often get on a lot better with your disc than you can with your coulters. By and large, I prefer the ordinary coulter drill, except that I am very conscious of the advantages of the discs where you are likely to get blockage with straw, etc.

DR. PAYNE : On the question of wheel marks, I think that narrow strip wheel marks every 10 feet, or however wide your drill was, would not do any serious damage to the soil structure at all.

DR. PIZER : I would say that the placement drill saves a loss of moisture from the soil, and probably that is its main benefit. If you have a deep furrow and start cultivating to get rid of it, you are going to lose a lot of moisture in some springs. In these terms, apart from any compression at all, this conservation of moisture I would say is the principal thing.

I would like to put in a plea for a certain amount of " smear." I think it sometimes useful, particularly on potato ridges.

MR. HAWKINS : I would ask Dr. Pizer where the potato roots were drawing that moisture ? Are they in the ridge or below it ? The plant probably relies more on roots below the ridge than roots in the ridge. I tend to be influenced in my potato cultivations by what I have seen on the Continent, where the principle has long been to make the best use you can of the heat of the sun, particularly in Scandinavia, where their season is short and they like to get their seed potatoes in as soon as they dare and then keep them near the sun so that they are warm, and only gradually ease the soil over them as is necessary to stop them from greening. We tend to put up high ridges when they are not always necessary.

DR. PIZER: Certainly it is the moisture below the ridge which gives you the crop eventually, but in the early stages there is always a risk of quite a bit of scorch to potatoes from the fertiliser put in the ridge, and we do see this in dry times, particularly where people use large amounts. Perhaps the answer is to use less fertiliser, but at any rate in a ridge which tends to dry out fertiliser injury is nearly always higher than in a ridge which stays moist.

MR. CAVE: I like to plough all my land for peas, potatoes, sugar beet, with a one-way plough so that you do not have the furrows going across the field. I have different makes on the farm which make a very good job on my light to medium silts, but have not found one yet that will turn a furrow satisfactorily on my heavier soils. Is it possible to design a one-way plough to turn a furrow for the furrow to remain turned on the heavier land ?

MR. HAWKINS: Yes, my troubles on the heavier land with one-way ploughs have not been simple ones, but a combination of the fact that with one-way ploughs you are down to one or possibly two furrows behind a tractor on which you can press on a bit, and so you get the general troubles of ploughing faster than the body likes to plough on heavy land. It is probably more common with one-way ploughs because they are limited normally, with fully mounted ones anyway, to one or two furrows. I do not think that the bodies on one-way ploughs for the heavy soils of this country have received the attention that ordinary ploughs have received.

MR. J. J. A. KENDALL: As one of the two guinea-pigs whom Mr. Hawkins persuaded to import one of these ridging bodies from America, may I comment on them. I don't think it is really fair on our one experience this year to condemn them, as he said they are built for the American 36–40 in. row, and although we clipped the wings and the shares, we found they were far too wide for 28 in. We used them, but could not get nearly enough mould on to the ridge without doing damage to the potato roots. As a result, we got more drying out than when we used the standard British type of ridging body. We had a depressed yield from this type of body compared with our standard type.

The meeting ended with a vote of thanks to the speakers, proposed by Mr. Roger North and carried with acclamation.

DEVELOPMENT IN GRAIN DRILLS, BRITISH, AMERICAN AND CONTINENTAL

by M. A. DHUICQ,* M.I.B.A.E.

A Paper read at an Open Meeting of the Institution on Tuesday, 18th February, 1958

History

I WOULD like to make a short historical summary of the evolution of seeding machinery since mechanisation began to take the place of man in the 18th century. Although the use of a seeding machine was known in ancient times in the Middle East, it is almost certain that James Cooke proved the possibility of sowing seed by the use of a machine. What is most amazing is the fact that this first machine was a row seed-drill with coulters. But, during the 19th and at the beginning of the 20th centuries, the broadcasting type seeder appeared and became the most well known. Competition increased in the beginning of the 20th century, and after 150 years the seed-drill proved itself to be the best solution over the broadcaster. The reasons why can be divied into two groups :

(*a*) Better regularity of depth and coverage, with decreasing losses of grain.

(*b*) Greater yield due to the more even space given to each seed by the fixed dimension of the width.

For a moment, could I explain this second reason : With a broadcaster the seeds are spread at random, and due to the variation of wind, making air-whirls, the seed is sown unevenly, with varying areas of density. Where the seed is dense the roots are not able to develop without interfering with the roots of other seed. On the contrary, in spots of low density the roots find more than a sufficient volume of soil for the nutrition of the plant. The result is an uneven growth of the plants and subsequently a smaller yield than if the growth had been constant all over the field.

The use of the seed-drill is the first step in giving to each seed a constant volume of soil for nutrition by giving a constant dimension in one direction—the direction perpendicular to the travel of the machine, so the roots of the plant can develop sidewards to a constant width. This constant sideways is the main reason for greater yields, but has led to some other advantages only obtainable by this first improvement. Hoeing has been made possible between the rows, and I want to salute again James Cooke, whose seed-drill had a frame which was possible to use for cultivating so that competition between the plant and the weeds was checked. Lately, the placement of fertilizer aligned with the seeds has further increased the superiority of row-seeding.

The point I want to make is now fairly obvious. All the improvements previously described are due to even distribution in one direction, so the final attempt in seeding development should be to obtain even distribution in the row. By achieving this, an equal volume of soil would be given for nutrition to each seed, and certainly from this achievement new processes of hoeing or of fertilizing would add to the improvement of the seeding and cultivation.

Position Problem

So we come to equal spacing of seeds. The problem is to put the seeds in the row at equal distances. The dimension of the spacing is, of course, for a given width directly proportional to the rate of seeding per acre. This rate of seeding is calibrated and controlled on the present seed-drill by different devices of feeding mechanisms—free-feed, fluted feed, pegwheels, etc., the way of calibration being the volume and the speed of rotation of this volume in relation with the travel speed ; in some cases, the volume is constant and only the speed determines the delivery rate. For a given rate the volume remains theoretically constant and the speed is theoretically proportional to the ground speed, so the delivery should be proportional to the ground speed and the problem of spacing should be solved.

Unfortunately, things are not so simple and we can visualise it by taking a conventional seed-drill, for example, with a fluted feed, setting it at a very low rate with a medium-size grain like wheat. We calibrate it on a given number of revolutions of the feedshaft and count the grains delivered from one chute. As the length of travel can be calculated from the revolutions of the feedshaft, we know the theoretical distance between two following seeds. After that we put the seed-drill in the field, and on the same length we measure the distances between following seeds. If the observed distances are classified in categories varying by equal steps on the graph axis " ox," and if we put on the axis " oy " the numbers found in each category, we obtain what is called the frequency curve of the intervals. The ideal would be to have all the intervals in only one category. But what is found is completely different. The purpose of the design of a precision seeder is to have a frequency curve as close as possible with the peak curve.

Testing and Control of Accuracy

The statistical aspects of seedling distribution down the row have been considered in various Papers ; these involve the devising of some measure of the irregularity of the braird—*i.e.*, of the departure of the observed

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distribution from the ideal. Tests can be carried out either in the field or in the laboratory on greased boards, in which case some causes of discrepancy are removed. In both cases the result is a statistical analysis of the intervals found in the row or of the number of seeds in unit lengths of row.

The departure of an actual distribution from the ideal one (*i.e.*, such that the plants are equally spaced along the row) can be attributed to three causes, namely :

(*a*) Multiple placement—two seeds or more instead of one have been sown.

(*b*) Misses—no placement of seed.

(*c*) Variation of the intended interval.

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 1      2  3  4         5          6
 ×      ×  ×  ×         ×          ×
—O——————O——————O——————O——————O——————O——————
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If the interval is large, it may be possible to decide which of the three causes is responsible for an observed irregularity, in which case the accuracy of a planter or a precision seed-drill can be measured by the percentage of multiples, the percentage of misses, and the variation of the intervals. (The intervals will probably have a Gaussian distribution, the standard error of which is a measure of the variation.) We shall return to this three-category analysis of defects when dealing with the design of precision seed-drills.

When the interval between seedlings is shorter, this categorisation of defects obviously becomes confused, for the variation in the interval (category (*c*)) is not correspondingly reduced—it is, in fact, independent of the mean interval. Consequently, it is impossible to distinguish between errors of spacing, multiple placement, and misses, and the comparison with the ideal distribution cannot be made.

In this case, then, another criterion must be used, and the concept of *random* spacing is most convenient. It can be shown that when the seeds are randomly spaced along the row, the number of seeds in a unit length of row has a frequency distribution which follows the Poisson Law ; this implies that of all the intervals along the row, the proportion which exceed a length L is $e^{\frac{-L}{M}}$, where M is the (known) mean interval. A consequence of the assumption of the Poisson Law is that the statistic $\frac{\text{variance}}{\text{mean}}$ (calculated from the frequency distribution of the intervals) can be expected to have the value unity ; and the extent to which it varies from unity indicates how great is the departure of the actual distribution from the theoretical (random) one. The probability, assuming randomness, that the statistic $\frac{\text{variance}}{\text{mean}}$ will exceed, or be less than, an observed value can be calculated, and accordingly the hypothesis of randomness can be accepted or rejected. It should be noted that the statistic $\frac{\text{variance}}{\text{mean}}$ has value zero when the spacing is exactly regular, increases to approximately one for random spacing, and may be significantly larger than one if the seeds tend to be arranged in clusters. Thus, ideally, a precision seed-drill should give a distribution for which the $\frac{\text{variance}}{\text{mean}}$ ratio is zero ; if the ratio is not significantly less than one, the drill is achieving no more than a random distribution.

Another useful criterion, in the special case of sugar beet seeding, is the percentage of intervals smaller than a given value (*e.g.*, one-half the mean spacing).

Some other ways of comparing accuracy can be used, but the basic principle remains the same ; namely, that the distribution of intervals is compared with the random distribution, and that the drill is " penalised " for all spacings less than half, or greater than one-and-a-half, the mean interval. (Method of Prof. R. D. Barmington.)

Discrepancy Causes

Following the results of the analysis of the distribution of seeds and of the discrepancies shown relatively to a normal distribution, we can classify the reasons for discrepancies into different categories :

(*a*) *Slippage*. The seeding unit for one row has a metering device giving a seed interval linearly dependent on an angular or a linear displacement actuated by the travel on the soil. Actuation can be made either by one or two wheels per row unit or for several rows. In the latter case, the wheels can be the support wheels for the seeder and for the drive. Whatever the driving device, there could be positive or negative slippage. If the seed units are being driven by wheels which take their source of power direct from a tractor engine, one could have positive slippage or if the wheels are not directly attached to an engine there could be negative slippage. The way for improving accuracy can be based on : Decrease of torque needed for operation of the seeding unit mechanism ; dimension, weight of seeding unit wheels ; use of metering devices driven from tractor wheels, if traction required is small relative to tractor power ; speed of travel because many of the results shown previously are affected by speed, and we can guess that very low speeds close to zero minimise these discrepancies.

(*b*) *Press-Wheels and Chains*. After the furrow has been opened and the seed put in it, there is the closing of the furrow over the seed. This operation is made by chains or more often by press-wheels. These chains or press-wheels can displace the seed either by motion of the soil or by adherence of seed to the soil and soil to the press-wheels. Action to reduce the risks of displacement by these devices can be taken mainly on their shape and also on materials to decrease soil adhesion.

(*c*) *Tubes*. It is not possible to have the seed put directly on the soil in the furrow at the output of the metering device without an interval in time and consequently in travel. During this interval of falling between the metering device and the soil the travel speed can change inadvertently, so causing a difference in the spacing, even if the time in falling has remained the same. Just to show the relative proportion between the falling time and the spacing, I shall take a very simple example. For seeds one inch apart, with travelling speed of 2 ft. per second, the time between the metering of two following seeds is roughly ·04 sec. For a free fall of 1 ft. the falling time is ·25 sec. or six times the theoretical spacing time. The result is that a variation in the travel speed, in the falling time, or falling travel, of only 16 per cent. will give a double or a miss.

It is admitted there are no very quick changes in the speed of a seed-drill, except at the beginning or at the end of a row. But the change in falling travel or falling time can be affected by different conditions—wind action between the outlet of the metering device and the tube ; bumping against the walls of the tube ; direction of the seed travel relative to the angle and the dimension of the tube ; rugosity of the tube ; change in the value of the speed of the seed at the outlet of the metering device and rebounds on the ground.

Wind action can be eliminated by having the seed tube and the feed outlet joined without a gap.

Theoretically, bumping against the walls could be avoided by a seed having no horizontal component of the speed. In fact, by a very simple calculation it is possible to find the diameter of a vertical tube knowing the height of fall, the expulsion speed if any and the travel speed. Or *vice versa* with a given drill or planter it is possible to know the maximum travel speed which can be used allowing for the height and diameter of the tube. For example, taking the figures used before of 1 ft. of fall, 2 ft./sec. of travel speed ; the diameter of a vertical seed tube would be minimum 6 ins., with seed speed of zero at the outlet of the metering device. With this dimension it is almost certain that there will be no contact of the seed with the wall of the tube.

This seed tube dimension could be decreased in different ways :

Giving to the seed a vertically-directed expulsion force so that the time of fall would be shortened and made small in relation to spacing time.

Shortening the time of fall by having the lowest possible position of the outlet of the metering device over the soil.

Accommodating the angle and the dimension of the tube with the relative travel of the seed. The angle would be a parabola determined by the expulsion force and the travel speed.

If, even with these precautions, there are still some contacts between the seed and the tube this contact will be made at a very flat angle, and if there is no rugosity on the inside of the tube the length of travel and the speed of the seed will not be noticeably affected.

I apologise for having taken so long on this question of discrepancies due to the tubes. My purpose was to give you the idea that the placing of the seeding units near the ground, as is done on a big percentage of precision seed-drills, is not a real necessity. It is possible to think of other methods perhaps more practical for reducing close to zero the influence of the tube on the regularity of the spacing, considering as nil the variation of air resistance with the variation of seed shape or dimension, during a seeding operation.

(*d*) *Doubles in Metering Device.* I have made a distinction between apparent doubles and real doubles. Real doubles are obtained when two seeds are taken inside the device which has been normally designed for selecting at a given interval only one seed in the mass of seeds coming from the hopper. The method of avoiding this anomaly is basically the same in many devices—it consists in brushing away the extra seeds collected at the same time as the normal selected seed.

(*e*) *Real Miss.* There is nothing to say on this, as the object of the metering device is to get one seed. The design is as accurate as the number of misses is close to zero. As the grading of the seed cannot be perfect, and sometimes is almost impossible, there should be no misses even with some variations in shape and dimension of the seed. On the other hand, it should not be necessary to make elaborate changes to the metering device when changing from one type of seed to another.

(*f*) *Seed Injuries.* A good precision seeding unit should avoid all injury to the seed. Even if the regularity of spacing is perfect, if one seed in three has been badly damaged and does not germinate, the results are as bad as with a seeding unit having a lot of misses. This applies mostly to the types giving an expulsion speed to the seed and for those which brush off the extra seeds unduly collected.

DESCRIPTION OF THE DIFFERENT DEVICES USED IN PRECISION SEEDING

A. The most known and the first device used for this purpose is the *horizontal cell plate*, which had its origin in the corn planter. The principle is very well known—a horizontal maize plate having cells of a given dimension at its periphery rotates partly inside the hopper and partly over the tube. Devices are used for avoiding doubles and sometimes there is a type of ejector helping the seed through the cell.

It can be understood in this kind of planter that the risks of having a cell not filled increase when the amount of grain inside the hopper decreases. That is the reason for some device having curves at the bottom of the hopper to collect the grains just over the cells. Another way which is used in some British or European seeders is to tilt the whole unit at an angle to have an accumulation of seeds on part of the outside diameter. The separation of the hopper itself from the room where the seed is ejected is a feature which is found fairly often, sometimes combining with it a narrowing passage to the point of fall, avoiding real cut-off action.

Risk of injury to the seed is the main difficulty to overcome in the two actions of avoiding doubles and ejection. Injuries could happen if the screen, between the hopper itself and the point where the seed is ejected, is too rigid. Instead of metallic parts one finds a rubber curtain, rubber roller or flexible brush. This last item can also be used for the ejection. Even with these improvements and with fairly good regularity of spacing the cell-plate models have still a certain percentage of damaged seeds, as shown in results of tests made in various countries.

There is another criticism. It is necessary to change the cell-plate when changing seeds, and sometimes if the dimension of the seed or the seeding rate changes (I found a catalogue with more than 20 cell-plates for maize alone). In fact, to obtain good results it is necessary for smaller seeds to be graded, and it is one of the reasons why sugar-beet seeds have been pelleted, so that a good calibration was more easy and the results of the seeding units better. But, as you know, the question of segmented and pelleted sugar-beet seeds involves other than the purely mechanical problems I am trying to describe.

Another point which has been criticised is the risk of bridging which seems higher in a hopper when the mass of seeds is rotated by the bottom of the hopper. One of the worries of the designer has been agitators. The problem is to know that they are efficient and that this efficiency is not the beginning of reasons for seed injuries.

B. Drum Type

In this model the cells, instead of being through a circular plate, are on the outside of a horizontal cylinder, and they are only cavities instead of holes. The principle is simple—the hopper is on the top of the cylinder, the seeds are directly in contact with the cells in the outside circumference, where there is a screen around the vertical section of the cylinder from the hopper to an opening at the bottom where the seed is released and falls by gravity.

The idea in this kind of metering device was to give some of the advantages of the cell-plate type. It is also possible to increase the diameter of the drum without affecting the overall width of the unit, which is not possible with the cell-plate type, so having a very small area of the cylinder in contact with the seeds in the hopper. In this area the motion is practically linear and the speed of parts in contact with seeds is constant. In the cell-plate type the speeds vary from zero in the centre to the speed of the cells at the outside ; consequently, the bridging of seeds is lower with the drum type. In principle, it can be claimed that the filling of the cells should be better in the drum type and a smaller number of misses found.

As far as doubles are concerned, the problem remains practically the same—there is a need for a cut-off before the screen which makes the passage up to the falling point. In this rea the risks of damage by the cut-off device and by friction along the screen remain about the same as in the cell-plate type.

At the falling point, the seed leaves its cell by gravity ; there is no ejection device and so no risk of damage. But as this point can be only very close to the vertical of the axis of the cylinder, the seed is given a certain horizontal speed relative to the unit. This increases the discrepancy on the travel and time of falling, unless the speed is the same, but opposite to travel speed so that the speed is zero relatively to soil. Certainly, it is one of the reasons why the units using this kind of device are very close to the ground. If it is proved that a knocker giving ejection speed is necessary, the drum should be thin and holes would replace cavities ; there would be an inside screen to avoid the seeds passing through the holes, and a knocker would be put inside the drum in the lowest area. It means a more elaborate device than the drum first described, but normally it is simpler than the cell-plate unit.

Changing the cell drum at the same time as the seed type or the seed dimension remains exactly as in the cell-plate type.

From the results of tests made by official testing stations in laboratories and fields, it does not seem that the regularity has been found better than with the cell-plate type, but the damage percentage has been found lower. As there are at the present far more models of cell-plate type than the drum type, it is not yet possible to make a deffinite comparison of advantages and disadvantages.

C. Rubber Belt Type

The damage to seeds by metallic parts is one of the main problems designers have tried to solve. This is the reason for some devices now on the market using rubber parts.

Starting from the drum type, which was already an advantage from this point of view, there has been made a model having rubber drums, but of relatively small dimensions. This device was fitted with an ejector for pushing the seed from the cell, because the friction between rubber and seed was higher than between metal and seed. The results in tests were best with pelleted and graded seeds. Though the seeds are brittle, it is easy to obtain good regularity of sowing.

As it was not possible to increase indefinitely the diameter of the drum, and because the flat travel in line inside the hopper could be considered as a real improvement in principle, the designers moved one step more—from the drum to the belt, which was giving the exact answer to this flat travel at uniform speed.

There are different methods of using the belt.

In one device the belt is perforated by holes and the seed is positioned in the holes of the belt over a spring base closing the bottom of the holes and is ejected by a roller through the belt. A cylinder turning in the opposite direction to the belt ensures the positioning of one seed inside each hole, acts as a cut-off device to avoid doubles and agitates the seeds over the belt to avoid bridging. In this unit the belt is moving in the seed drill, so that the relative horizontal speed with the ground is zero to avoid rebounds on the soil. As the unit or tube horizontal speed is noticeable relative to the seed rebounds could be found on the walls of the seed tube, so these units are made very close to the ground. I think that the fall height is about 1 in.

In another device there are two belts driven by pulleys on an almost vertical axis (on the previous device the axis of driving pulleys was horizontal) ; the outside edge of each belt is squraely cut and the two belts form a moving longitudinal slot. From the bottom of the hopper, which has a rectangular opening just over the moving slot, the seeds fall and align one behind the other. At the end the two belts part, leaving the seed, which drops on the ground. A rotary brush made of rubber is placed over the outlet slot in the bottom of the hopper to avoid extra seeds being carried out by the seeds already aligned on the slot. The direction of travel of the belt is opposite to the direction of travel of the unit to the ground. Because the seeds are touching each other (which was not the case in the previously described arrangement where the spacing of the cells on the belt can be matched or approximately matched with the spacing on the ground), the speed of the belt is slower than the travel speed over the ground. There is a noticeable speed of the seed over the ground, with risk of soil rebounds, especially if the forward travel speed of the unit is relatively high. However, the speed of the seed relative to the unit itself is low and so would allow the use of a tube with a limited length of fall without risk of interference with the walls of the tube. In most cases, the height of fall is a few inches only.

If we try to compare the general advantages of these two devices with the types described previously, it is mostly the fact of not damaging the seeds which is the outstanding improvement and which has been proved by the laboratory and field tests in various countries.

The regularity of sowing is good compared with the other devices, but is still better with the perforated belt, which theoretically allows a speed of zero relative to the ground, and where the distance on the belt between following seeds is not affected by the shape or position of the seed as it is on the slot-belt type.

For the first belt device described the problem of changing seed is the same as in the cell-plate or drum type—it is necessary to supply a new set of belts and other small items. The change is even necessary when changing the spacing for a same seed, otherwise the advantage of the zero speed is partly lost. In the second device the width of the slot can be adjusted to the dimension of seed by increasing or decreasing the distance between the two belts, so that this seeder can be considered as almost universal. The rate of seeding is largely controlled by the size of seeds which are touching each other. It is adjusted by variation of belt speed and there is the possibility of high rates, as the distance between seeds is the smallest possible, allowing reasonable belt speeds. This is not the case in the other type where the seeds are apart, and so for high-speed rates the speed must be proportionately multiplied.

D. Vibration Type

From what I know, only one type of precision seeder has been made on the principle of vibration. It was marketed for some years in France, but it does not seem to be sold now. The principle was to put the seeds in a slot like in the second belt device, all the seeds being aligned in this slot, which was a mechanical gutter with provision for increasing the width. This gutter was not horizontal, but had a slope of about 15 per cent., and there was a knocking device giving a vertical shock to the end of the gutter and ejecting one seed inside the tube chute. This design has many of the advantages of the belt type, but the impact speed given just before the fall to the ground was a source of spacing discrepancy, even with a small time of fall. The advantage was that the design was fairly universal because of the ability to increase the width of the slot.

E. Pneumatic Types

As we shall see, the idea of a pneumatic seed drill is not new, but it is only during the past two years that pneumatic precision seeders are beginning to be marketed. It is for this reason it can be considered the latest development in precision seeding.

We have found patents dating from 1922 and 1923 in which were described different processes for picking seeds on tubes or on holes in a wheel by suction, the extra seeds sticking around the seed in front of the hole being shaken away by vibration. The seed picked by the hole is allowed to fall some way on the travel by a screen which cuts off the suction. One of the most interesting patents is the German one, No. 389,840 of 1923, which really applied to precision seeding, has the pneumatic device, and is used for selecting single seeds, putting them in a bucket-chain delivering the seed just over the ground at a minimum height of fall and at a given distance from one another.

In nearly all of these old patents can be found all the principles and advantages of the pneumatic seeders now in operation in Russia, Germany and France.

The principle is to have a small hole in a moving part, which can be a tube, a wheel, a plate, a cylinder, etc. ; one side is in contact with the seeds in the hopper ; the other side is connected to a source of aspiration, which can be a compressor or even the inlet of the tractor engine. Methods exist for preventing other seeds sticking on the hole and being carried with it. This can be by mechanical means like a brush, a roller, vibrations, or it may be pneumatic. The latter is by blowing off the extra seeds, the adherence of which is less than that of the seed actually on the hole. Finally, the aspiration on the other side of the hole is cut by a screen, a roller or any other mechanical way. Better still, it is put to atmospheric pressure or a blow of air to give extra speed to the fall of the seed.

The advantages are really noticeable. The same hole can accommodate seeds of a very wide range in dimensions, as it has no relation with the diameter of the seed. The hole is relatively small, yet it creates a clinging action sufficient for big seeds, even counteracting friction or pressure of the remaining seeds on the outside of the selected seed. This kind of seeding device can be considered as being universal. There should be no misses, as in practice the seed is drawn to the hole. To have a double, it would be necessary for two seeds to arrive simultaneously on the hole and cover it by half; if not, one would have less adherence than the other and will be ejected by the cut-off device, especially if the device consists of an air jet. The damage to seeds is nil, as there is no relative motion of solid metallic or even rubber parts to the seed, and also as there is no ejector acting directly on the seed. At the point of ejection the direction and the value of the speed can be chosen as required to obtain good regularity just as easily as with the best designed mechanical precision seeders.

The three types I know differ by some detailed features.

In the Russian seeder, the holes are perforated on a cylinder inside which there is reduced pressure by aspiration. At a portion of the circumference grain is collected in the laterally placed hopper and with a small agitator at the bottom. A brush takes away the extra seeds near the top of the travel of the cylinder. Almost on the lower horizontal plane of the cylinder axis a rubber roller cuts off the depression and the seed is ejected into the seed tube with the linear speed of the drum, so decreasing the time of fall. It is claimed that this device can be applied to a full seed drill with a cylinder the width of the seed drill and with a series of holes corresponding to the number of rows.

In the French type the holes are perforated in the periphery of a plate, one side of which is in contact with a space fed with seeds from the hopper, in which there is an agitator; the other side is towards a suction chamber attached to an aspirator. The plate is turned vertically around a horizontal axis in the direction of and with a linear speed opposite to the travel speed. This has the advantage of zero speed to the soil, but it is necessary to change the perforated plate when changing the spacing. The seed is freed when the plate passes over a suction cut-off area with a hole giving atmospheric pressure on the side opposite to the seed. One of the other advantages claimed by the manufacturer is the fact that the seed can be seen by the operator during the travel from the hopper to the point of fall. The number of parts is very small.

In the German type the metering device is also a perforated plate turning on a horizontal axis. The compressor gives suction to the chamber opposite to the hopper; at the same time, air blows on the plate near the upper part of its travel to take off any extra seeds which are clinging around the seed in the middle of the hole. Almost at the lower part air blows through the hole and ejects the seed towards the ground. The height of fall being about 10 ins. is more than in the French type, which has no blowing action on the falling seed. This seeder is marketed now in Germany for sugar beet seed; developments and testing are going on with maize and wheat.

Interesting results have been obtained with these two French and German models during the last season of maize planting in the South of France.

Before finishing with the pneumatic type, I should like to describe two German patents which I understand have not yet been manufactured, but they are a new approach to precision seeding. Their basic ideas are the same—that is, to have a tube of a given length—say, 5 ft., for example—with perforated holes spaced at exactly the required seed spacing; this tube is positioned on the drill parallel to the direction of travel. The pneumatic action is alternatively suck and blow. The seeds are collected by all the holes of the tube and are all freed at the same time, periods of suction and release action being such that successive lengths of the tube placed seed are apart by theoretically one seed spacing. Of course, it is very far from a patent to the production of a machine and to the marketing. There will be many problems to be solved on a machine of this kind—furrow openers, covering, timing, etc., but I thought you would be interested in this idea, which is so different from the machines presently known.

Up to now the seed spacing drills are only used for a small percentage of the total crops of Europe. They apply only for some seed like maize, sugar-beet and some vegetable seeds, for which the economy of using them is obvious by bigger yield or less man-labour, even taking into account their price, which is still higher than a conventional seed drill. However, experiments are being carried out in various countries with some of the mechanisms I have described to see if economy, by increased yields or less seed, can be obtained by their use in general crops like wheat, especially in areas where wheat is hoed. It is possible that in future years, due to better and less expensive mechanisms, the economy will be such that seed spacing drills will slowly but surely take the place of ordinary seed drills.

DISCUSSION

MR. G. G. HERVEY MURRAY (National Institute of Agricultural Botany): There are two aspects which I should like to discuss. Firstly, I want to deal with the basic theme which appears to run through the Paper and which points to the need to make seed drills more efficient.

My work at the N.I.A.B. leads me to believe that if seed drills could be made more efficient in the way suggested by M. Dhuicq, smaller quantities of seed may be required to sow given areas, and, as a result of this economy, farmers might be persuaded to buy high-quality seed and consequently obtain more efficient and rewarding results.

Many disappointing crops are caused by inefficient seed drills and methods. As Mr. Dhuicq mentioned, overcrowding results in excessive competition for the available nutrients. Overcrowding provides conditions which are conducive to infection from injurious diseases, results in the production of grain which is small and uneven and, more often than not, causes serious lodging, which in itself causes serious losses and harvesting difficulties. With uneven spacing there will be overcrowding in certain areas, while gaps will be taken over by weeds and these will lower the quality of the crop. Evenly-spaced seed should result in the use of the minimum quantity of seed, which should be of the highest quality. The resulting crop will be uniform, true to type and free from weeds and diseases and should produce grain of even quality.

There appears to be a growing need for seed-spacing drills for certain specialised work. Plant breeders need machines which are capable of sowing a large number of ear-row plots.

Nine years ago we were faced with the prospect of having to sow each year approximately 1,500 cereal samples in small vertification plots at Cambridge. Each sample had been drawn from a different stock of seed and was to be tested for trueness-to-type, and its freedom from varietal and other impurities was to be observed and recorded.

We wanted a seed drill which could sow approximately 1 lb. of seed, down to and including the last grain, at a given and even rate. It had to sow a plot of 7 drills, each 7 ins. apart and 50 ft. long. Also, it had to be capable of being cleaned out completely so that not one grain remained to contaminate the next sample. So far as we could discover at that time, no such drill existed. I am happy to say, however, that, thanks to the ingenuity of certain members of the staff at Wrest Park, we do now possess a drill which satisfies our requirements.

MR. P. HEBBLETHWAITE (Silsoe) : May I add my thanks to those of the previous speaker for this Paper. I learned over tea that Mr. Dhuicq wrote this Paper in English, which I think is a tremendous achievement.

There are, however, certain points which, before the Paper goes on record, ought to be looked at in some detail. I think Mr. Dhuicq has had some difficulty because he has got so much material into such a small space, particularly in relation to the statistics. I think that in that process the material has suffered a little.

The main theme of this Paper is that there is a possible economy in seed, and improvement in yield to be gained from " spacing " cereals. I think that that is a fairly revolutionary statement and I think it does a lot of good to question conventional methods in this way. I think, however, that we must be a little careful before we damn the conventional. All the spacing drills on the market at present operate at up to 2 mp.h. If we are to use a spacing drill for cereals it must go a lot faster than this. Farmers are looking for speeds of at least 4 m.p.h., and they are willing to pay quite a lot for it. Without the extra speed, and even if it effects an economy equivalent to a bushel of seed an acre, the adoption of spacing drills for cereals would at the moment be an expensive move.

Following a little on what the previous speaker has said, I think we should look at the possibilities of the best conventional mechanisms which are available before we attempt to adopt expensive spacing methods. He mentioned a drill which was built at the N.I.A.E. which apparently give him satisfactory distribution in the row. The metering mechanism of that drill is conventional and it is not in any way a spacing drill. Perhaps the answer should come first from the crop husbandry people. We must know the advantages of accurate spacing before the agricultural engineer goes to a lot of trouble to produce a machine which may not be an economic proposition. The answer can be fairly easily obtained, because plots can be laid down without too much expense and then we can see the extent of the economies.

Mr. Dhuicq mentioned the method of assessing evenness of distribution along the row. He referred to the Poisson distribution and I think he conveyed the impression that that was related to a random distribution along the row and that that was the worst possible distribution. Unfortunately, that is not true. It is possible to get a worse distribution than the Poisson distribution and therefore we have to be a little careful about applying what is said on that point in the Paper.

One factor which was left out of consideration was instantaneous change of speed of the drill in relation to length of seed tube and so on. Probably many of us remember the work of Dr. Cornelius Davis, which showed fantastic instantaneous changes of speed in horse drilling. I think there may be slight changes in the speed of a grain drill behind a tractor. The changes of speed are only instantaneous, but they cannot necessarily be disregarded.

There is one question which I should like to ask. Does the speed per second mentioned on page 3 of the Paper refer to the tractor or to the velocity of the seed ?

M. DHUICQ : It refers to the speed of the tractor.

MR. HEBBLETHWAITE : In that case I think we are working on the wrong lines if we say that we need a tube with a minimum diameter of 6 ins. To take another example, if you stand in a moving train and drop a penny it hits the floor at a point immediately below its point of release. That will happen although the velocity of the penny relative to the earth is perhaps 60 m.p.h. A tube of small diameter would suffice to contain the trajectory of the penny because the horizontal velocity of the penny and of the floor relative to the earth are equal and constant. Thus to anyone in the train the penny will appear to fall vertically.

M. DHUICQ : The question is to know what is the exact velocity of the seed to the ground.

MR. HEBBLETHWAITE : I am only saying that the only horizontal velocity which the seed has relative to the drill or seed tube is that which a metering mechanism may give to it.

Another point in relation to the seed tube is the significance of the aerodynamics of the seed. I think it is a dangerous step to neglect this factor, and having done so to argue that perhaps we do not need very short seed tubes on spacing drills. The nearer the tube is to the ground the less error there will be in the spacing of long seeds if they fall in different attitudes.

M. DHUICQ, in reply, said : I agree that better quality seed will cost the farmer more and that therefore there is a need for drill units which have the maximum of efficiency. Although such units will have to be marketed at a higher cost, the farmer will get a better yield, because the risk of damage to the seed will be lower.

I am in entire agreement with Mr. Hebblethwaite on the historical aspect of the matter. I think the idea of seed drilling originated in Italy and I believe that the first drill made was used in Austria at the beginning of the 18th century.

On the fluted type there are two sources of calibration —the volume and the speed. All discrepancies affecting the calibration would generally change the volume. When it is desired to decrease the rate of seeding the volume is decreased, but the play of the parts remains exactly the same, so the percentage of discrepancies increases when the volume is decreased. In the peg-wheel type the change is only a change of speed, so that troubles are fewer whatever the rate of seeding. That is one of the advantages of the peg-wheel type.

Mr. Hebblethwaite said that it is possible to have a worse distribution than the Poisson distribution. I should like more information about that, because Poisson law is random law and it is very difficult to find anything worse.

On the question of length of tube, I agree that with the minimum rate of fall there will be the minimum discrepancy because one of the causes of discrepancy has been suppressed. For the time being, I do not think we can envisage the possibility of sowing wheat seed at very small widths with individual units. It would be a very expensive device.

I agree that any change in the level of the ground would affect the time of fall and would cause discrepancies as far as the conventional seed drill is concerned. This would not apply to individual units because they are less affected by changes in ground level from one side of the seed drill to the other.

MR. D. R. BOMFORD : I gather that one of the objects of these seed feeding mechanisms is to discharge the seed at no horizontal movement in relation to the ground. Is that so ? If that is so, then there is no relative movement between the seed and the ground, but there is relative movement of the drill between both the seed and the ground. That is the reason for the large-diameter tube which M. Dhuricq mentioned. Need that tube be cylindrical ? Could it be an oval or an oblong ?

Supposing these factors are ignored and you allow the seed to leave the feed mechanism at the speed of movement of the drill, and supposing you use a small tube so that the seed leaves the tube at the speed of movement of the drill ; then I am sure that the seed will behave like a cricket ball and will bounce along the ground. Would there be a cure for this by so designing the coulter of the drill that the seed was trapped between the closing sides of the channel immediately it made contact with the ground ? We had this trouble with some of the early potato planters, and in that case it was to some extent possible to trap the potato immediately on contact. I wonder whether some of the complications of the seed mechanism might be got over by ignoring the relative movement and trapping the seed with the soil in this way.

M. DHUICQ, in reply, said : The speed of the precision seeder is very low, being about 1 to 1½ miles an hour. With a high speed of 4 miles an hour the risks would be greater and that it why it would be necessary to achieve a relatively low speed between the seed and the ground. It is a fact that on practically all the field tests made on precision seeders of different kinds it has been found that even with a low distance of fall the results were better with devices having a low speed of the seed relative to the ground. In some cases trapping the seed would certainly be a good solution. In a certain way, of course, it would only be a compromise, because it might give rise to new causes for discrepancies. It could, for example, move the soil too much in the process of trapping the seed or, if there was some moving part in the soil, there might be displacement of the soil.

COL. JOHNSON : I am very ignorant about seed devices, but I have read the Paper through and have tried to absorb it. Tha first thing that struck me about it was the complications from the design point of view that must arise from the various sizes and shapes of seed. It seems to me that perhaps insufficient consideration has been given to that point. Surely it is possible to pellet seeds, no matter what their size or shape, to one or two standard sizes. There might be international standards for the pellets and that would surely greatly simplify the design of all seed drills.

I should like to know what Mr. Dhuicq thinks about the idea of the pelleting of seeds.

M. DHUICQ, in reply, said : I think the idea of pelleting seeds is one which would be a very great help to engineers who design seed drills. If there were two, or even three, sizes of seed it would enable engineers to increase the efficiency of seed drills.

MR. J. R. WARE : There are one or two practical points which have been brought out by the Paper. First of all, how accurate do we really want these seed drills to be ?

I am using an old-fashioned cup feed type of drill made 60 or 70 years ago, and it will sow sugar beet almost as accurately as some of the lesser known spacing drills. Those plants have to be singled just as much. I may use, perhaps, a few more seeds per acre. The machine can be drawn at a fast horse speed, perhaps 3 or 3½ miles an hour, whereas some of the accurate machines can only do 1½ to 2 miles an hour. Speed is of fundamental importance in this country, where our weather conditions are not reliable.

What we want is a drill which can place the seed as nearly accurately as we require as fast as possible. Speeds of 4 miles an hour and more are what we want.

If we are going to have very accurate machines, we have got to have a fairly universal type of coulter to deal with all types of soil and conditions. Again, can these accurate machines cope with some of our sandy, abrasive conditions ?

M. DHUICQ : Some of the causes of discrepancies can be considered to be simple ones, and improvements can be made in conventional seed drills.

MR. D. R. BOMFORD : Seed falling without any movement in relation to the ground will fall at a speed relative to G, which will be a constant for a given height. The horizontal movement of the drill itself will not be a constant. Mr. Dhuicq gave us a dimension for the tube, which may be a cylinder or an oval, for a given height. Can he tell us the speed at which that dimension is calculated and whether the dimension will become excessive at, for example, a speed of 6 miles an hour ? Would it, for example, be 2 or 3 feet ?

M. DHUICQ : Yes. The unit is moving and the seed is falling straight to the ground with no velocity, but relative to the seeding unit it is a parabola. It is, therefore, possible to find the angle of tube which will give a small dimension.

MR. R. M. CHAMBERS : You have to allow for variations in the speed of travel and that determines the width of tube. The speed of travel of precision drills, as we know them, is relatively slow. What about the speed of travel of the pneumatic type of drill ?

M. DHUICQ : It is claimed that they can work at two or even three miles an hour.

THE PRESIDENT : In Italy two years ago I saw a wheat field with the plants 18 ins. apart. They had tillered out and it was a marvellous crop of wheat. On making enquiries, I was told that with their hotter season it was all right because there was even ripening, but with wide rows here you would get as good a crop but uneven ripening of the tillered stocks. Would that have any bearing on the standard 7 ins. ?

In Sweden and Finland it is down as low as 4 ins. Does the width of row influence the even ripening ?

MR. BOMFORD : I think that some light might be thrown on that by the experiments carried out by Walter Dunn. He made what he called a surface drill for very shallow sowing and claimed as many as 100 ears from a single seed. This, I think, has a bearing on spacing, because the plant had a shape about 9 ins. wide. I borrowed his drill and I cannot say that I ever achieved 100 ears, but it was possible to find 50 ears per seed. That sounds very encouraging. On one occasion, however, the crop failed entirely, so it did not seem worth worth following up the experiment, germination having failed through drought.

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Hon. Sec. : C. V. H. Foulkes, B.Sc., C.I.B.A.E., County Education Offices, Stracey Road, Norwich, Norfolk.

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Chairman : R. L. Wilkinson, A.M.I.B.A.E.

Hon. Sec. : L. West, B.Sc., A.M.I.B.A.E., "Ivy Hatch," Little Lane, Welbourn, Lincolnshire.

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Hon. Sec. : G. S. Bowman, A.M.I.B.A.E., 22, Craigleith View, Edinburgh, 4.

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WESTERN

Chairman : H. T. Horsman, M.B.E., B.Sc., M.I.B.A.E.

Hon. Sec. : J. R. Robertson, N.D.A., N.D.D., N.D.Agr.E., A.M.I.B.A.E., Naish Hill Cottage, Lacock, Wilts.

YORKSHIRE

Chairman : H. E. Ashfield, M.I.Mech.E., M.I.B.A.E.

Hon. Sec. : G. G. Baldwin, M.A. (Eng.), A.M.I.B.A.E., ~~35~~, Barlow Road, Keighley, Yorkshire.

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The following Elections were effected by the Council from January to March, 1958 :

MEMBERS

Andersen, P. B. : Scotland
Clark, D. : Yorkshire
Mann, S. : Yorkshire

Overseas

Poole, H. G. : Southern Rhodesia
Rodriques-Arias, J. H. : Puerto Rico

COMPANION

Coleman, P. G. : Surrey

ASSOCIATE MEMBERS

Anslow, A. : Lincolnshire
Brown, K. D. : Scotland
Jackson, G. : Norfolk
Mole, A. G. : Buckinghamshire
Noblett, F. : Warwickshire
Perry, D. C. : Berkshire
Reyner, J. M. : Yorkshire
Shovelton, P. L. W. : Buckinghamshire
Warburton, J. A. : Lancashire

Overseas

Sen Gupta, S. K. : India
Subramaniam, J. J. : Ceylon

ASSOCIATES

Atkinson, M. : Norfolk
Bolton, P. : Durham
Coleman, A. : Lincolnshire
Crawford, A. : Ayrshire
Gibb, H. R. S. : Northumberland
Joice, J. T. : Norfolk
Luke, A. : Durham
Peach, L. S. : Gloucestershire
Rae, N. Mc : Scotland
Rowe, T. J. : Cambridgeshire
Ridley, Hon. M. W. : Northumberland
Whatley, G. : Berkshire
Widdowson, R. : Yorkshire

Overseas

Blair, W. : Southern Rhodesia
Mann, V. B. S. : India

GRADUATES

Bolstridge, A. : Warwickshire
Clough, M. G. : Gloucestershire
Dent, B. J. : Northamptonshire
Gupta, R. : Northumberland
Howland, J. L. : Warwickshire

Overseas

Reid, W. S. : Ghana

STUDENTS

Aldington, T. J. : Essex
Baly, E. N. : London
Evans, G. H. : Essex
Findlay, J. S. A. Yorkshire
May, B. A. : Kent
Riordan, E. B. : London
Robertson, J. S. : Middlesex
Shaw, P. G. : Essex

Overseas

Thoniappa, T. : India
Verma, B. P. : India

TRANSFERS

FROM ASSOCIATE TO MEMBER

Chambers, R. M. : Warwickshire

FROM ASSOCIATE TO ASSOCIATE MEMBER

Campbell, J. H. : Warwickshire
De Las Casas, R. V. : Warwickshire
Rampley, A. J. : Norfolk
Walton, R. : Warwickshire

Overseas

Ekanayaka, B. I. D. I. : Ceylon

FROM GRADUATE TO ASSOCIATE MEMBER

Dow, J. A. : Perthshire
Linton, D. E. : Staffordshire

Overseas

Barr, O. S. : Uganda
Carpenter, L. J. : Brunei

FROM GRADUATE TO ASSOCIATE

Taylor, S. A. : Lincolnshire

Overseas

Goodale, N. : N. Rhodesia
Saraswati, R. N. : India

FROM STUDENT TO ASSOCIATE MEMBER

Paterson, H. : Middlesex

FROM STUDENT TO GRADUATE

Evans, R. B. : Sussex

I.B.A.E. REPRESENTATIVES ABROAD

AUSTRALIA (New South Wales)

J. A. Alkinson, M.I.A.Mech.E., A.M.I.B.A.E., Department of Agriculture, Sydney.

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NEW ZEALAND

A. W. Riddolls, B.Sc., A.M.I.Mech.E., M.I.B.A.E., Lincoln College P.B., Christchurch, New Zealand.

NIGERIA

R. T. Lewis, B.Sc., M.Sc., A.M.I.B.A.E., Faculty of Agriculture, University College, Ibadan.

PAKISTAN

P. J. Venables, A.M.I.B.A.E., Eden Buildings, Dacca, East Pakistan.

CENTRAL AFRICA

L. Tourle, M.I.B.A.E., Bentalls (Rhodesia), Ltd., Box 737, Salisbury, Southern Rhodesia.

KENYA

S. D. Minto, B.Sc. (Agric.), M.B.E., M.I.B.A.E., East African Tractors and Implements Testing Unit, Box 22, Nakuru, Kenya, British East Africa.

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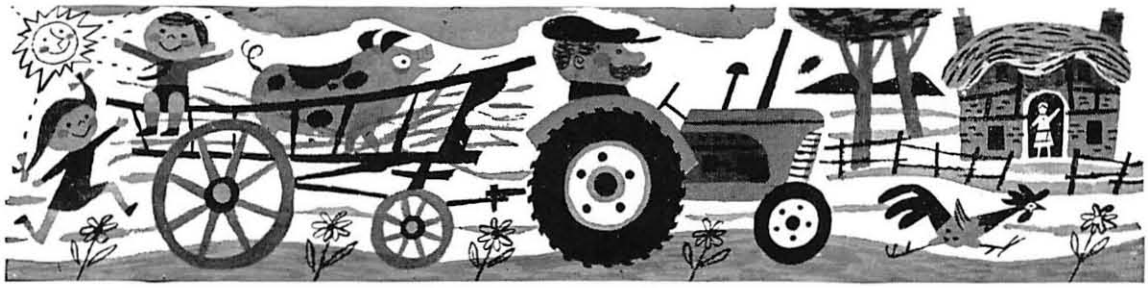

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