# JOURNAL AND PROCEEDINGS OF THE

# INSTITUTION OF AGRICULTURAL ENGINEERS

VOL. 17 NO. 1 - JANUARY 1961

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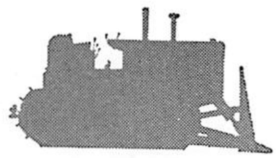
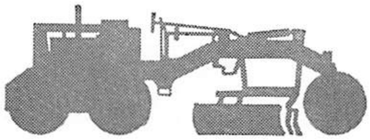
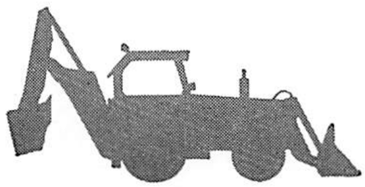

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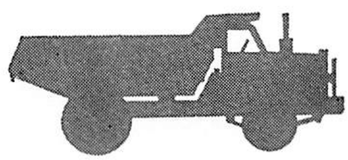
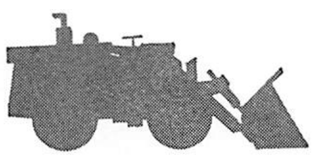
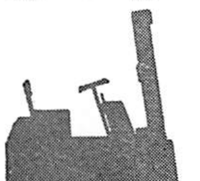
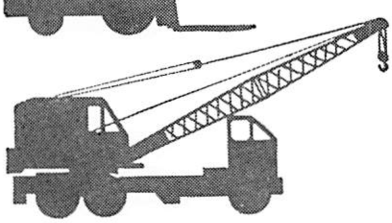

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# JOURNAL AND PROCEEDINGS OF THE INSTITUTION OF AGRICULTURAL ENGINEERS

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*CONTENTS*



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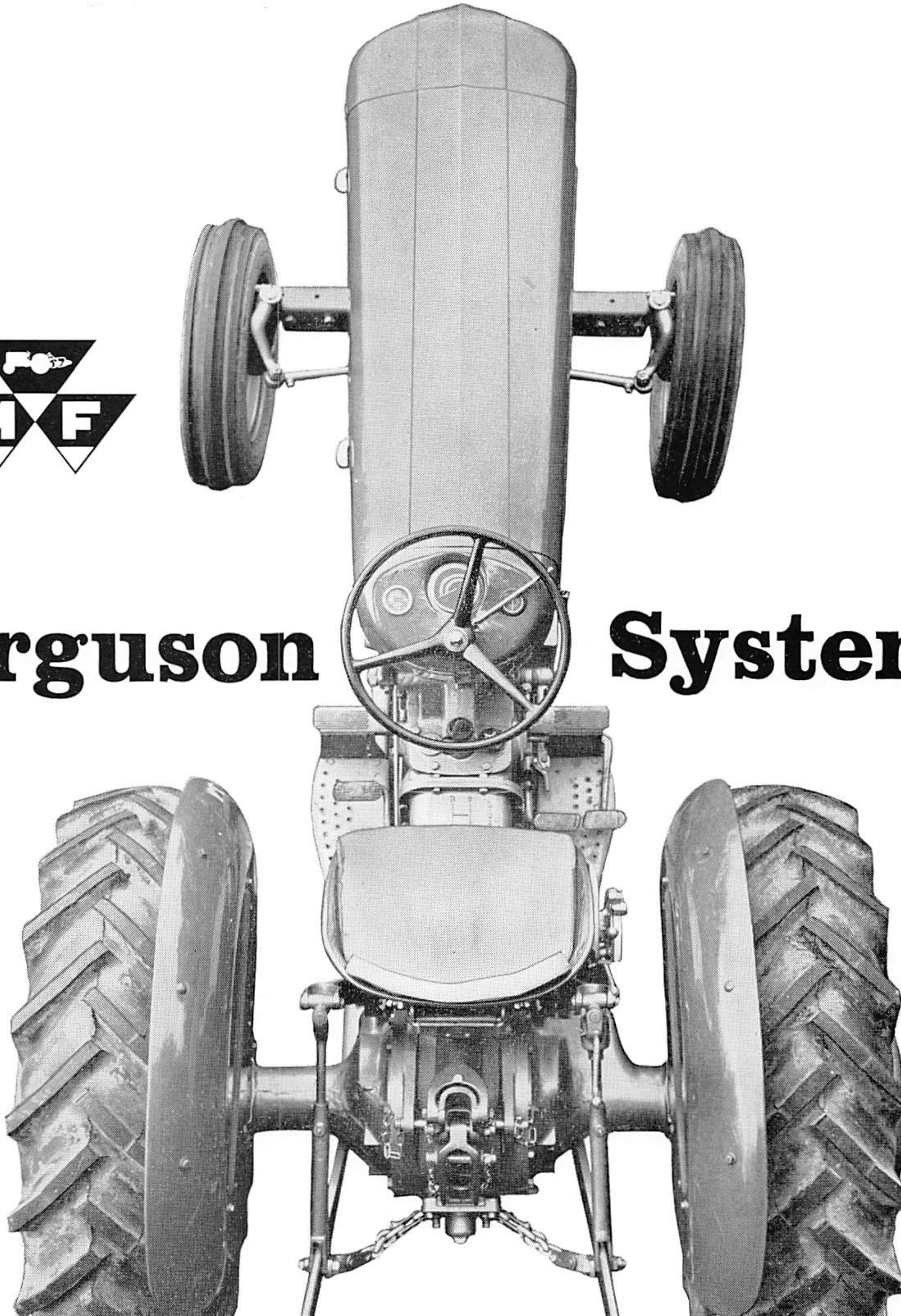

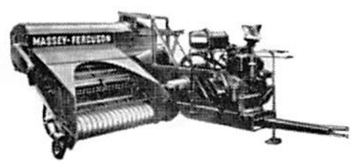

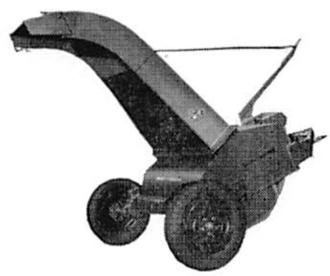

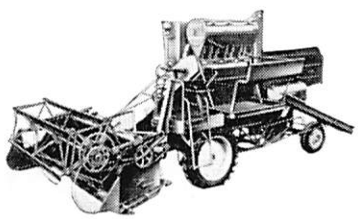

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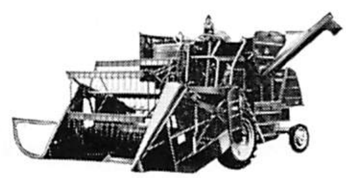

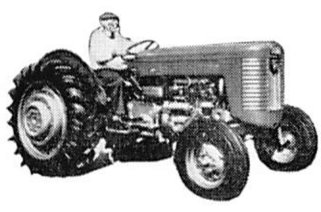

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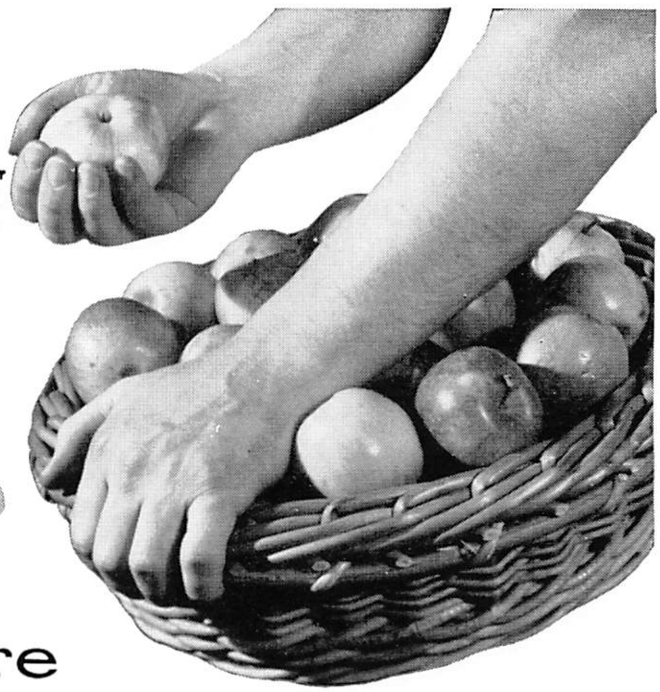

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# INSTITUTION NOTES



### Annual Meeting, 1961

PARTICULARS of the Annual Conference of the Institution, which will follow the Annual General Meeting on April 25th next, are given in the letter enclosed with this issue. As this Meeting is the first of its kind, the Council hopes that as many members as possible will attend.

### Commonwealth Technical Training Week

The Institution is co-operating with the London County Council, and other bodies in connection with careers exhibitions and conferences to be held throughout the country during Commonwealth Technical Training Week, May 29th – June 4th, 1961. It is likely that talks will be given in London and in the Branches, with visual aids made available by the co-operation of the Agricultural Engineers' Association.

### C.I.G.R. Meeting in Paris

The Commission Internationale de Génie Rurale, of which the Institution is a member body, has arranged a series of Papers for presentation during the week preceding the Paris Salon.

Mr. J. H. W. Wilder, a former Vice-President of the Institution, is to read a Paper on Forage Harvesters on March 9th. The Meeting will be held at Antony, near Paris.

### International Conference on the Mechanics of Soil - Vehicle Systems

An International Conference on this subject will be held in Turin, Italy, from June 5th to 9th, 1961. History, theoretical and experimental research and new developments will be dealt with in the Papers to be presented. Members who would like further particulars should write to A. R. Reece, B.Sc., M.Sc., A.M.I.Mech.E., A.M.I.Agr.E., University of Durham, Kings College, Dept. of Agricultural Engineering, Stephenson Building, Claremont Road, Newcastle-upon-Tyne, 2.

### This Issue

Apologies are expressed for the delay in publication of this issue of the Journal. This has been occasioned by certain difficulties in connection with the Paper on the reclamation of land from the sea, which will now appear in the April issue.

## LIBRARY

Books received :

**Farm Implements for Arid and Tropical Regions,** by H. J. Hopper, Farm Implement Specialist, Agricultural Engineering Branch, Food and Agriculture Organisation of the United Nations.

**Agricultural Machinery Workshops, Design, Equipment and Management.** F.A.O.

**Symposium on Mechanical Cultivation in Uganda.** Department of Agriculture, Uganda.

**" Power to Produce "—United States Department of Agriculture**

" Power to Produce " presents a comprehensive and well-illustrated survey of the development of agricultural engineering and other sciences and skills ancillary to agriculture. Its interest is not confined to the boundaries of North America. The progress of agricultural mechanisation is revealed as a chain, whereof the most recently forged link is itself seen as a prototype for future developments in mechanisation and extention in automation. Modern techniques and equipment in all branches of agriculture are discerningly reviewed against the economic and at times sociological background.

# THE MECHANICAL HANDLING OF FARM MATERIALS

*by* J. A. C. Gibb,* M.A., M.Sc., M.A.S.A.E., M.I.Agr.E.

*A Paper presented at an Open Meeting on Tuesday, 15th November,* 1960.

**Summary**

MUCH agricultural work is concerned with the movement and handling of various materials—seeds, fertilisers and manures, feeding-stuffs, dung, and crop and animal products. The small scale of many individual handling tasks, the layout of buildings and of farms, the difficult nature of the materials themselves and the conditions in which they are dealt with, are all among the factors which lead to the employment of much manual labour for such work.

In manufacturing industry, materials handling is now an accredited science. To what extent can scientific materials handling principles be applied to farm work? This Paper seeks to relate these principles to agricultural practice, and refers also to a variety of methods which have been developed in Great Britain and abroad to meet specific handling requirements. Use of the standard agricultural tractor, equipped with handling attachments, is suggested as a possible solution to many farm handling problems. The importance of planning farm handling operations as a whole is stressed, with special reference to design of buildings and other layout considerations.

**Introduction**

In manufacturing industry and in the commercial distribution of goods and materials, Materials Handling is now a recognised branch of study. On practically all farms, materials handling accounts for at least 30 per cent. of man and tractor work, and on many farms the figure may reach 50 per cent. or more. Yet comparatively little is known of the handling requirements of agriculture, and practically no scientific data is available to guide farmers in their selection and management of handling equipment. In fact, only two Papers (1, 2) with any bearing on this subject had been presented to this Institution up to the middle of 1959. In the 1959/60 session we were fortunate enough to hear Papers on silage handling (3) and on milk handling (4) here in London, while the E. Midlands and Northern Centres also discussed materials handling from the work study viewpoint (5), and the handling and preparation of feeding stuffs (6).

Only within the last year or two, in fact, has it become widely recognised that handling and transport operations account for a considerable proportion of the total cost of labour employed on farms. It is also realised that much of this work is carried out with equipment, or by methods, or in conditions, that makes inefficient use of labour.

* *Lecturer in Farm Mechanisation, University of Reading.*

Because expenditure on labour is now the major outgoing on many farms, and because labour is becoming increasingly scarce and expensive, mechanical methods of handling many kinds of farm materials are of vital interest to farmers. Such methods will normally save labour by increasing the work output of the men engaged on handling tasks, rather than by replacing the men altogether. Complete automation of some handling tasks is quite possible, from an engineering viewpoint, but is frequently considered undesirable, either on economic or farm management and supervisory grounds.

In covering the field under discussion we must first establish, in general terms, the principles to be applied, then note the limitations imposed by agricultural conditions, and finally assess the potentialities of the methods of handling available to the farmer.

**The Principles of Handling**

These have been stated many times in recent years, but it is appropriate to restate them here, as drawn up by one authority (7).

(*a*) Minimise handling of all kinds, since it adds nothing but cost to the finished product.

(*b*) Never move more than once between processes where this can be avoided.

(*c*) Integrate materials handling with the process. Do not consider it as an ancillary.

(*d*) Plan handling as systematically as a direct operation of production; study layout with the object of reducing the distance and number of times material is moved.

(*e*) Never decide on the designs for new buildings until the handling operations have been planned.

(*f*) Work should be done on materials while in transit wherever this is economical, practical and safe.

(*g*) Persuade your suppliers to deliver materials to you in the most convenient form and size for handling.

(*h*) Study the range and number of containers with the object of reducing them.

(*i*) Never place materials directly on the floor; put them on a pallet or dunnage.

(*j*) Use gravity where possible.

(*k*) Mechanise where economical.

(*l*) Maintain the planned system of handling; see that unauthorised changes do not creep in.

(*m*) Continue to examine the system for possible improvements.

As stated, the above principles are intended to be directly applicable to industrial circumstances. Yet little change in terminology is required to bring home their relevance to farm work. Some, admittedly, have greater immediate importance to farming than others, but none should be ignored.

### Limitations

Compared with most industrial circumstances, farm handling tasks present many difficulties. A United Nations report (8) considers these against the background of European agriculture, and also examines the characteristics of the goods and materials concerned.

To summarise the difficulties, it may be said that much handling work on the farm is concerned with relatively small quantities of each of a large number of different materials of comparatively low intrinsic value. These materials are often unpleasant or difficult to load by reason of their nature—*e.g.*, farmyard manure, sugar beet, fertilisers, etc.—and have to be moved over surfaces that are slippery, or soft, or rough. In addition, the dimensions and layout of buildings, the arrangement of buildings within the farmyard and the poor quality of many farm roadways all combine to detract from efficient handling.

On the credit side three factors may be noted, so far as British farming is concerned. Firstly, almost all tractors and trailers and other farm transport vehicles are now equipped with pneumatic tyres. These, in conjunction with the second factor—good public roads between farms—permit relatively high transport speeds, at least for transport off the farm. In the third place, practically all tractors now have take-off points for both hydraulic and mechanical power, which can be applied to handling requirements.

### Agricultural Trailers

The farmer's equipment for *transport* purposes is therefore often adequate. Indeed a tractor and trailer is almost the only form of transport equipment, which can cater for the wide variety of goods in question, permitted by some of the conditions met regularly on farms. But transport, in the sense of movement from one place to another, is only one stage of a handling operation, and on most farms it is allied to loading and unloading stages that are either quite unmechanised, or at best make poor use of labour. Furthermore, use of trailers alone is not in accord with the majority of the handling principles and is severely restricted by space limitations in farm buildings.

However, trailers may yet form part of a planned approach to mechanical handling, and a number of improved features may be of importance. Where ground conditions are particularly bad, power take-off drive to the trailer wheels may be employed, though this can only satisfactorily be done where facilities for a ground-speed p.t-o. are available on the tractor. Tipping facilities, both rearwards and sideways, have been available conveniently since hydraulic systems became standard equipment on tractors, and these provide a means of unloading bulk materials where there is no objection to placing the materials directly on the ground. Some trailers have been designed to allow ultra-low loading, permitting goods to be wheeled on to the trailer platform by means of sack trucks or similar devices. The loaded trailer bed is then elevated to the normal position, and it may also be tipped for unloading purposes.

American-designed self-unloading trailers are now appearing in this country, and for most purposes have all the advantages of tipping trailers. They have additional advantages in that food materials can, to some extent at least, be mixed before delivery, and that delivery can be controlled and need not necessarily be to ground level—it may be into mangers, conveyor hoppers, etc. Also, because a 4-wheeled chassis can be employed, weights of individual loads may be greater.

There is no doubt that tipping and self-unloading trailers can make a substantial contribution towards the handling problems of British farmers for many years to come. However, at best, they can only carry out transport and unloading functions, and the efficiency of labour utilisation depends not only on the means of loading in the first place, but also on the means of disposing of the unloaded material. These will invariably be conveyors of one kind or another.

### Conveyors

A conveyor, like a trailer, may introduce loading and unloading problems. When handling a free-flowing material such as grain these are least troublesome, since one can arrange for the material to flow by gravity to the conveyor entry-point, and to fall from the delivery-point into storage, or wherever else it is required. If the material is not free flowing, like grass or bales, too often use of a conveyor involves a man at each end to load and unload.

For conveyors to be fully effective, feeding and disposal facilities must also be mechanised. This may require the provision of a horizontal receiving trough which delivers to the elevating or conveying portion of a conveyor, and it may involve a further distribution or delivery conveyor at the other end.

While conveyors of many kinds are in use on farms, the versatility of auger types is specially noteworthy. Even though many operating conditions result in low efficiencies in terms of through-put in relation to the horse-power input, the simplicity, robustness and comparatively low cost of auger conveyors should encourage farmers to use them to an ever-greater extent. A new conveying and elevating principle, employing a continuous belt formed into a tube, has given promising results in America, on an experimental scale, and may offer higher specific throughputs than present types. There is no reason why quite large portable elevators of general-purpose types should not be used more than at present, provided satisfactory feeding and disposal arrangements are made.

### Industrial Equipment

In industry, materials handling is to a great extent effected by means of a vast range of types of conveyors, often automatically or semi-automatically controlled by electronic means. This fixed equipment is supplemented by self-propelled vehicles such as stillage trucks and fork-lift trucks, allied to a system of movement of materials in unit loads on pallets or stillages. Clearly the use of conveyors in agriculture can be extended, and some types of automatic control may be adopted. The introduction of unit loads and pallet systems, however, calls for discussion.

A unit load consists of one or more objects so arranged as to be conveniently handled mechanically. Some unit loads may be of such a nature that neither a platform nor a container is necessary, and in such a case all that is required is to deposit the load on dunnage strips laid on the ground, in order to maintain a working clearance for a lift fork of standard dimensions. Most often, however, a platform or a box pallet will be required to form either a base or a container for the load. Pallets should be of standard dimensions and should permit stacking on top of each other in storage by means of a fork lift of some kind. Stillages are generally not restricted to standard dimensions, and may or may not be stackable.

The equipment for handling industrial unit loads comprises fork-lift trucks and pallet and stillage trucks of various types. Fork-lift trucks are used primarily for stacking unit loads, and may also be used for short-distance transport purposes. Where stacking is not required and transport distances are greater, much cheaper pallet- or stillage-trucks may be used. It is important to note the main characteristics of the fork-lift truck. It will lift weights of 1 to 10 tons to heights of 12 to 20 feet, depending on the model. It has a heavy chassis, small wheels and low ground clearance in order to provide maximum stability. The cheapest fork-lift truck designed for a riding operator costs more than twice as much as a standard farm tractor.

From the agricultural point of view the ordinary fork-lift truck has many disadvantages. It is far too expensive for the great majority of farms to justify, it has too little ground clearance, and is ill adapted to slippery and rough agricultural surfaces. The same considerations apply to pallet trucks.

### Unit Loads in Agriculture

Before considering use of the fork-lift principle in agriculture, it is relevant to ask what unit loads offer to the farmer. The main advantage of mechanically-handled unit loads, as such, is that the lifting capacity of a man is multiplied by a large factor. In addition, a pallet system allows optimum use of storage space, and pallets or containers afford a means either of grouping smaller loads—*e.g.*, sacks, bales, etc.—or of subdividing bulk materials, such as feeding-stuffs. Further, a pallet system can be made to conform with most of the handling principles already referred to. One can envisage considerable economies in labour in the reception, handling and storage of many kinds of bought-in material—*e.g.*, fertilisers, seeds and feeding-stuffs. Such a system also makes it possible to standardise on containers or methods of delivery that are convenient for handling.

It is possible to use industrial pallet and fork-lift trucks in agriculture, and a small minority of farmers do so. Well-paved farmyards are essential, and it is unlikely that the equipment can be used intensively enough to justify its cost. If the farm operations extend into horticulture, and much of the cost can be written off against activities in, say, a fruit store and packhouse, the case is much sounder. Some farmers have compromised by making their own fork-lift trucks, but the skill and time necessary for such an enterprise are rare.

### Farm Pallet Handling Equipment

For the great majority of farmers, special-purpose handling vehicles are therefore out of the question and one is forced to seek an alternative if pallet systems are to be adopted. The conventional farm tractor at once appears to offer a suitable basic vehicle, and also provides a hydraulic system, of limited capacity, which may be used to power handling attachments. From the economic viewpoint there is an obvious advantage in making additional use of tractors, whose overhead costs are already spread to a great extent over the various production enterprises.

The first possible approach is to make an attachment to simulate, as closely as possible, the industrial fork lift.

FIG. 1.
A rear-mounted tractor fork-lift attachment of 10-15 cwt. capacity.

One type of fork-lift attachment fits on to a special sub-frame bolted to the rear of the tractor, and is operated by the tractor hydraulic system through a pair of four-way valves. A hydraulic ram is provided to tilt the lift fork forwards and backwards, and a second ram extends and retracts the telescopic mast, raising and lowering the fork. The fork itself conforms to standard dimensions, and is pivoted at the rear so that it can be folded upwards and out of the way if the tractor is used for other operations. Such operations include trailer work, and an automatic hitch lifting hook is provided beneath the mast for this purpose. The unit may thus load a trailer, transport the goods and unload it at the destination.

The maximum height to which such a fork-lift attachment will raise a load is about 10 ft. 6 ins., and the weight-lifting capacity is within the range 10 to 15 cwt., depending on the type of tractor used. Front-wheel weights are essential.

In operation it is necessary for the tractor driver to look over his shoulder, which may limit precision of control. However, farm-tractor operators are used to this, and it is not likely to be such an important disadvantage on the farm as it would be for intensive use in industry. The mast-tilting ram is necessary in order to cant the forks down when entering a pallet, and to cant the mast back and prevent the pallet sliding off when it is raised.

Another type of rear-mounted fork lift is designed to raise 1-ton loads to a maximum height of 5 ft. 6 ins.—adequate for loading lorries. This unit has been designed primarily to meet the needs of fruit growers, but obviously has potentialities for other more general applications.

FIG. 2.
A low-clearance rear-mounted fork lift of up to 1 ton capacity.

Some American manufacturers market fork-lift attachments, but, whether front- or rear-mounted, these are intended as permanent modifications of the tractor, and it would not be practicable to mount and dismount the attachment at frequent intervals. The tractor seat and controls are reversed on the rear-mounted types.

**Use of Tractor Loaders**

A second possibility is to make use of the hydraulic tractor loader now to be found on very many farms. Then there is an opportunity of reducing still further the capital cost of the equipment required for handling, since practically all that is needed is a working head. The majority of loaders are front mounted, though some are rear mounted, and a few have universal mountings which permit changing from front to rear operation with a few minutes' work. A limitation of the ordinary loader, however, is that it provides only the lifting function, and, further, the working head moves in an arc, canting backwards as it rises.

The first stage of modification is therefore to provide two sets of attachment points on the head, and a parallel linkage on the loader boom. The working head then remains level at all heights. Unfortunately, however, lost motion in the various linkages and tractor tyre deflection under load combine to allow the fork tines to slope down slightly, especially at ground level just as the pallet is first lifted. It may thus tend to slip off the forks. One manufacturer has overcome this by incorporating a pair of pull-rams in the parallel linkage, so that the fork can be tilted back for lifting or transport purposes through an angle of about 15 degrees.

Yet another limitation of the conventional loader is that the boom is rather long, which is a desirable feature when the loader is used to handle farmyard manure. Unfortunately it means that the weight-lifting capacity is not at a maximum, and also that the tractor-loader outfit is less manœuvrable than otherwise. The answer is of course a short-boom loader, which is less suitable than the standard type for other farm loading tasks.

**Limitations of Tractor Loaders**

Rear-mounted loaders offer advantages in manœuvrability, and in carrying the load on rear tyres of large section. Further, the mounting and hydraulic arrangements are direct and simple. Against this must be set the major disadvantage of over-the-shoulder operation, unless the seat and controls are reversed. The factor limiting the load weight is likely to be the hydraulic system rather than any mechanical consideration. The height of lift may be limited by reduced stability of the tractor when a load is fully lifted.

FIG. 3.
A side-tipping pallet fork mounted on a tractor front-end loader with parallel linkage attachments. The pallet shown is suitable for handling about 5 cwt. of potatoes.

Front-mounted loaders are subject to different limitations, of a mechanical nature, which tend to override the hydraulic factors. Thus a typical front loader may well be capable of raising weights of 12 to 15 cwt., assuming conventional hydraulic oil pressures, to heights of 10 feet or more. The same loader can be made to lift greater weights by using rams of larger diameter, at the expense of slower operation, and probably reduced maximum height. This potential performance, however, is limited in practical circumstances by the stresses imposed on various components of the tractor.

The main factor to be considered is the transference of weight from the rear wheels to the front. This results in diminished rear-wheel adhesion, which may be counteracted by the addition of wheel-weights, water ballast, strakes, a lift-mounted concrete weight or a second loaded pallet carried on a rear-mounted fork. A second effect is to increase the weight acting on the front axle and front wheels. It is thus likely to prove advantageous to fit front tyres of larger section and of a heavier rating, not only to absorb these stresses, but also to minimise the effort required to steer the tractor.

Clearly the magnitude of the stresses acting on the tractor front-end components is proportional to the total weight of the front loader and its load. It also depends, to a very important extent, on the operating conditions. Two operating conditions in particular greatly increase the instantaneous stresses. The first occurs when the load is lowered rapidly, and stopped suddenly before it reaches the ground. The second occurs when the tractor and loader are travelling on rough surfaces. The loader boom then tends to bounce, and at the moment when each downward movement ceases the instantaneous stresses are extremely high. From work at the National Institute of Agricultural Engineering (9) it appears that under these conditions loads of about 10 cwt. may give rise to stresses at the front axle of 15,000 lb. or more. Such stresses are sufficient to flatten tyres, buckle wheel rims, and on occasion break front axles or their mountings, while with some designs of loader the tensile forces tending to stretch the tractor along its axis are also very considerable.

A point of practical significance which arises is that the magnitude of these forces is also affected by the weight carried on the rear of the tractor. If little rear weight is carried, the shock forces referred to may be diminished by the tractor pitching forward as they are applied. When considerable weight is carried at the rear, effective forward pitching is reduced and the instantaneous downward forces remain at a high maximum.

From these results one concludes that with present tractor designs a 5-cwt. load on a front loader is invariably safe, that a 7-cwt. load is usually practicable, and that 10 cwt. may be too heavy and must certainly be regarded as the maximum load allowable for handling purposes. In the latter case movement over rough surfaces should be kept to a minimum. Further, it must be borne in mind that the practice of carrying a second load on a carrying fork at the rear, while it may be desirable from the labour use viewpoint, and while it gives the operator a sense of greater tractor stability, in fact multiplies the stresses to which the tractor front-end components are subjected.

**Practical Applications of Pallet Handling**

Up to the present time there have been three main centres of interest in the use of pallets or containers for farm purposes. These are for handling fruit in the orchard and to the packhouse, in handling potatoes from the field to the store, and in the handling of feeding-stuffs in bulk.

For fruit handling—mainly confined to apples and pears—the industrial type of fork-lift truck comes most nearly into its own, at least in the packhouse area.

FIG. 4.
A home-made fork-lift truck designed and built by a Canadian fruit grower.

Other means of moving loaded pallets to the packhouse must be adopted. The development of rear-mounted fork-lift attachments, which make no pretence of stacking higher than the platform of a lorry, is of interest. Front loaders with forks and parallel linkages are also used, but the height available in orchards is often limited and restricts their use to some extent.

Pallet systems of handling potatoes have aroused considerable interest in recent years, and various types of equipment have been developed. The first essential is to devise a pallet container which is of reasonable capacity without being too high for pickers to fill it easily. One type of pallet is lifted from the bottom in a more or less conventional manner, while another is lifted from a point above the ground by means of built-in shoulders.

A feature of the pallet system for potatoes is that the containers are usually tipped either into a trailer or straight into a bulk store, and both sideways- and forward-tipping forks are available. Tipping may be by gravity, with a hydraulic ram to return the fork to the locked position, or it may be under complete control by means of a double-acting hydraulic ram, as in the latter instance. In designing equipment of this kind, the importance of reliability and safety in operation must be kept very much in mind.

**Bulk Feeding-Stuffs**

The economies offered by handling feeding-stuffs in bulk may well be appreciable, both for the supplier and for the farmer. However, the capital investment required to make it possible, especially for the supplier, may be comparatively large. One method of utilising the merchant's existing flat-bed lorries has been developed which employs a bulk unit consisting of four separate 1-ton bins. Each of these can be tipped independently to the side of the lorry. The whole unit can be removed from the lorry or replaced in a very short time. Such a container unit could deliver into small bulk bins, each containing 5 to 7 cwt., which can easily be made waterproof and then used for temporary storage. The bulk bins are normally transported by a tractor equipped with either a cheap and simple rear-mounted carrying fork, or a tipping fork on a parallel linkage, or both. For movement inside buildings a special pallet-barrow is available or, in very narrow passages, a roller unit may be used, located directly under the bin.

Systems of this kind can be used to provide a means of handling not only feeding-stuffs, but also roughages, small animals such as pigs, poultry, etc., manure, fertilisers, and so on. Temporary storage in containers may well be economically sound and stacking may be possible in suitable buildings. The same possibilities are now being suggested for potatoes, although the overhead cost of containers for storage, each used only once per season, may be rather high.

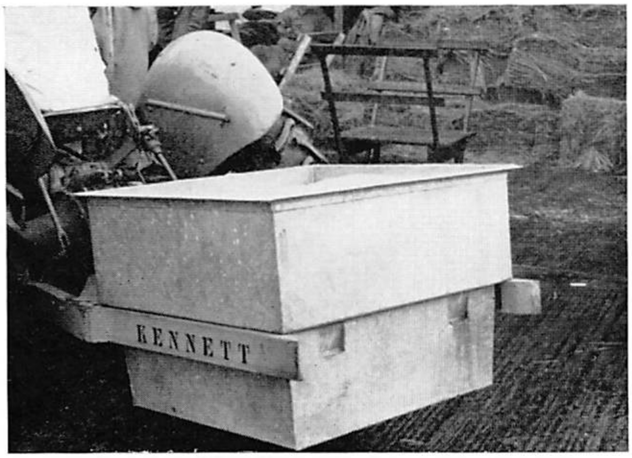


FIG. 5.
A simple container carrying fork mounted on the tractor 3-point linkage.

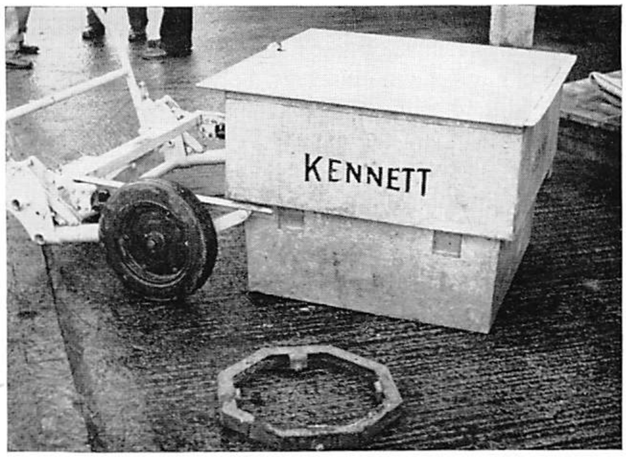


FIG. 6.
Alternative means of moving containers : The container-truck affords an easy means of carrying containers within and around buildings, while the roller-trolley can be used, situated directly under the container, in narrow gangways wherever there is a smooth, hard surface.

**Future Developments**

All the equipment mentioned is in use on farms to-day, at least on a limited scale. With increasing labour costs the use of handling equipment must become more widespread. The salient feature of the present situation would appear to be the need to concentrate on the integration of handling activities on the farm to conform more nearly to the ideal principles of handling. This is likely to involve greater use of fixed and portable conveyors, in some cases controlled automatically, as well as a thorough appraisal of the advantages pallet systems may offer the farmer for handling purposes within the farm organisation. However, farm production is largely dependent on movement of raw materials on to the farm, and of finished produce off the farm, and the co-operation of buyers and suppliers with regard to palletisation or bulk handling is most desirable, and indeed essential, if all parties are to obtain the maximum benefit.

The part farm buildings have to play in influencing handling procedures must not be ignored. Too often existing buildings prevent, or limit, the adoption of efficient handling methods. With the current awareness of the need for improved handling methods there can be no excuse for failing to give full consideration to the handling activities associated with every new building, at a very early stage in its planning. Particular attention must be paid to such matters as access, floor bearing capacity, internal gangways, etc., and there is much to be said for modern types of wide-span construction.

This Paper has been concerned only with the basic principles of handling, with some of the implications, and with a few examples of types of system and equipment. There has not been the opportunity of dealing with some of the many fascinating systems of handling specific materials—for example, methods of handling orchard fruit in water in containers, methods of handling silage, of mixing and feeding concentrates, etc. Interesting and useful information on such topics is to be found in a number of recent publications (10, 11, 12), and one can only refer those interested to them.

## DISCUSSION

MR. JOHN M. CHAMBERS (Consulting Engineer) said that he had very little to criticise in Mr. Gibb's Paper and thought that opening the discussion could best be done by adding to the Paper. There were just one or two things in it to which he would like to draw attention. One was that, in discussing industrial fork lift trucks, Mr. Gibb had made the statement that they were too expensive for the farmer. Mr. Chambers said he would like to ask if they really were too expensive ? Obviously, the cost was more than the farmer had been accustomed to paying, but that was not the way to judge the question. Rather it ought to be judged by the ability of the truck to save labour and, at the same time, reduce cost, and he was sure there were some applications where they could be of considerable use to some farmers.

Talking about putting fork lift attachments on the tractor, he suggested that, because the tractor market in this country was just about saturated, farmers should consider using old tractors for this task, keeping them as material handling tractors until they were no longer reliable, which could be for a great number of years. In this way, mechanical handling with fork lift trucks need not be too expensive even on the smaller farms.

Mr. Chambers thought that Mr. Gibb did not take the materials handling question far enough, and asked where it started. He suggested that it started in handling seeds and fertilisers at sowing time. The handling of these materials in sacks was not good enough, and a method of handling in bulk must be devised which would be applicable to all farm sizes.

Materials handling of a crop in bulk started as soon as harvesting started, and labour-saving methods must be devised, including the packaging in bales, pallets or other form by the harvesting machine before the further handling took place.

On some combines in Norway, he had seen a system of combing in which pallet boxes were carried on the combine bagging platform. When filled, they were allowed to slide off the platform on to the ground and empty boxes were put in their place. The full ones were picked up by fork lift, taken to the farm buildings and the grain dried in pallets without any further handling. For the small farmer, he thought this was a satisfactory answer, rather than tanker combines with bulk handling methods.

Also in Norway he had seen collection and storage of potatoes in pallets, instead of the usual pallet system where the pallets are taken to bulk storage and emptied, the pallets returning to the field for a further load. The farmer concerned with the method of storing the potatoes in the pallets owned a saw-mill, and from timber no good for other use he made pallets at a cost of 15/- each. On making enquiries, Mr. Chambers had found that it would cost £2 10s. 0d. to £3 to make such pallets in this country, which might make them uneconomic.

He concluded by emphasising again that proper packaging in some form or another was essential as a beginning to good material handling methods.

MR. J. E. KENNETT (Kennett Handling Equipment, Ltd.) said that he also could find nothing whatever to criticise, but he thought that there were certain points which could be amplified. He stressed two of the principles of handling mentioned by Mr. Gibb. These were : (1) Use gravity where possible—but Mr. Kennett added the corollary that it was most important never to lift anything one inch higher than one had to ; and (2) never place materials directly on the floor—but he went on to say that he would rather express it as never put things down in a way that was going to cost time and effort to pick them up again. This second rule was broken almost every time material was put into a sack and almost every time it was put on a trailer. In fact, if someone did both these things he had broken just about every rule, although there were occasions upon which it was necessary.

Mr. Kennett thought that properly speaking the pallet was primarily a device for storage, whereas the stillage was a device for handling. It was often cheaper to provide temporary storage in the form of a stillage than to handle something twice. In lifting by stillage, all one was doing was following rule " 2," and lifting became the work of one man—and that not necessarily the same man all the time.

The stillage system merited a place on every farm ; it could be applied at very low cost because the most expensive part was the lifting operation, and means for doing this were already provided by the tractor manufacturer. The farmer with a modern tractor had in his hands a " maid of all work " with a built-in hydraulic system which would make the manufacturer of a fork-lift truck green with envy.

In his opinion, Mr. Gibb was right to urge suppliers to supply goods in a practicable form for handling, but the scope for pallets for storage, as opposed to stillages for handling, was relatively limited owing to the difference in idiom between industrial and agricultural handling.

The fertiliser manufacturer, he went on, handled his materials in units in the region of one ton or more, whereas farm handling would normally be based on the tractor which could not easily deal with a unit load of much more than 10 cwt. He emphasised the value of the stillage system in livestock feeding.

Referring to Mr. Chamber's comments, Mr. Kennett said that he was interested to hear about the grain put into boxes from the combine, as he had done the same thing in this country, and it was much cheaper than conventional forms of bulk handling, at least on the smaller farm.

MR. GIBB, replying to Mr. Chambers, said that he would be the last person to say any machine was too expensive for the farmer. No machine was too expensive, provided the cost could be justified in relation to the amount of work the machine was going to do. But handling did not occupy eight hours a day, and he was sure that the more expensive machines would not be justified on the majority of farms. There were cases where industrial types of fork-lift truck had been found economic, but most of our farms were comparatively small, and he thought one should look at ways of adapting existing equipment to bring mechanised handling within range of farmers.

On using cheap tractors, he said that this was fine, providing that the cheap tractor was not so cheap that its reliability was in question. He mentioned the safety aspect at this point, for when 10 cwt. was put into the air safety was an important consideration.

He said that before one could store in pallets the latter must be loaded. They had already seen examples of potato handling. There was one farmer in this country who said he could afford to store in 10 cwt. pallets which he makes himself from scrap materials. The difficulty here was that 10 cwt. was about the upper limit that seemed to be practicable from a technical standpoint.

About Mr. Kennett's remarks, Mr. Gibb said that he could not do more than emphasise them. Obviously, one must handle as well as possible, which implied handling to the minimum height and extent.

MR. DOUGLAS BOMFORD (Bomford Bros., Ltd.) said that Mr. Gibb had made a case for the advantages of putting mechanical handling equipment on the tractor frame, but he pointed out that the driver had his work behind him and had to make the best of a very bad job. Mr. Bomford hoped that he was not going away from the subject, but he wanted to draw attention to the fact that the driver had become accustomed to having to turn his head round and do two-directional work.

As examples, he cited ploughing, tilling, and work with back-mounted scrapers and bulldozers, etc. Surely it was time something was done about this. Mr. Gibb had said that it might be excusable because the tractor driver was used to it, and that showed how often it happened. Mr. Bomford suggested that the right position for the tractor driver was facing sideways, and said that he had always been surprised that no one had produced a tractor with a side-facing seat.

MR. G. B. H. SPEAR (Kent) referred particularly to pig and poultry farmers. He asked if it was possible for a farmer to use a small stillage truck carried on three or four caster wheels.

MR. GIBB'S reply was to ask, in turn, whether it would not be cheaper for these specialist farmers to buy secondhand tractors and use a special fork attachment.

MR. P. HEBBLETHWAITE (N.I.A.E.) said that the bulk lorry Mr. Gibb had shown them appealed to him because he thought feeding stuffs should be delivered to the farm in bulk in a container. The container could stay on the farm until the lorry came round again, and he thought the millers had to be persuaded to do this.

MR. GIBB agreed that such containers would be convenient, but said that the disadvantage was that they would then be expecting the miller to increase his investment still further, whereas the provision of storage containers was surely up to the farmer.

MR. T. P. GREGORY (Rex Paterson Farms, Ltd.) said that, in his experience, one could put grain on the ground and get it up again satisfactorily with an ordinary auger at a cost of about £50 to £60.

MR. GIBB pointed out that Mr. Gregory had chosen to mention the one material which was specially easy to handle, because it flowed easily. There was not only one possible system of handling materials on the farm. They must use conveyors, trailers, and, to complement these, stillages or pallets where appropriate. He prophesied that in 20 years' time there would be some trailers, more conveyors, and many pallets and stillages, and the equipment that went with them.

MR. G. HAYLES (Suffolk) drew attention to the problem of handling straw. He said that more and more farmers were using bale sledges and leaving the bales in batches of six to eight round the field. He asked what was the best way of overcoming this problem, the difficulty of which was illustrated by the many different approaches to mechanising it.

MR. GIBB said that so far he had come across only one completely labour-saving system of handling bales. It was developed by two firms in the U.S.A. and incorporated a bale-thrower on the baler. Bales were thrown into a high-sided trailer and delivered into random storage in the upper part of a building. But in this country we did not have the same storage conditions and were not used to random storage methods. There were thus reasons why that system might not be suitable over here.

MR. G. T. MERRYWEATHER (Goodyear Tyre & Rubber Co. (Gt. Britain), Ltd.) queried the point in the Paper about tyre instability when using a front stillage attachment. He asked if Mr. Gibb had tried filling tyres 100 per cent. with liquid to limit the increased deflection.

MR. GIBB said that he did not intend to imply that the deflection of tyres at the front of a tractor was a bad thing—in fact, it was a saving grace. Where the front axle might possibly be broken, or the wheel rims bent, etc., because of high stresses, tyre deflection was a good thing. But he did agree with Mr. Merryweather that ballast at the rear of a tractor could be valuable.

MR. J. R. MOFFATT (Rothamsted Experimental Station) was interested to hear of the idea of pallet handling of potatoes, not only from the point of view of labour-saving, but from that of reducing damage to the potatoes, which had not been mentioned. This was becoming more and more important because of pre-packaging. Stillage handling could help in that way because the potatoes were not handled so many times. He had one fear—that potatoes might suffer damage when pallets were being filled in the field by striking the bottom of the pallets when the latter were nearly empty, and thus being bruised. He wondered if the pallets could be made with a half-door in them.

MR. GIBB'S answer was that one potato grower in Essex claimed that, instead of there being more damage because of pallets, damage was reduced. Pickers would drop potatoes in from whatever height was convenient to them ; so he felt that the half-door would not be useful. It might be possible to line the bottom of pallets with a shock-reducing material, such as foamed plastic.

MR. C. DE B. CODRINGTON (Potato Marketing Board) mentioned a new market recently opened in Sheffield where consideration had been paid to allowing the maximum use of fork-lift trucks and mechanical handling. No comments had been made during the discussion, he said, on the use of weighing machines in the handling of farm materials.

MR. GIBB said that he had no direct answer to Mr. Codrington. Weighing material in bulk was very difficult, and the comparative ease of weighing small packaged units, such as sacks, was one of the latter's big advantages. Where roller conveyors were used to move bulk materials, a weighing machine could be incorporated.

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# MACHINERY REQUIREMENTS OF UNDER-DEVELOPED TERRITORIES

by W. FERGUSON,* M.Sc. (Agric.Eng.), B.Sc. (Eng.), A.M.I.Mech.E., Member A.S.A.E.

*A Paper presented at an Open Meeting of the West Midlands Branch on 28th November, 1960.*

## Introduction

SEVERAL Papers have been written on the specialised problems of mechanisation in different parts of the world. This Paper, however, deals with the problems from a general aspect. In presenting it, it is not my purpose to review failures of schemes in Africa or to decry the efforts of good men who have tried to make them succeed. Let us admit that the British have had failures. All the major powers have made mistakes whilst attempting to make rapid agricultural developments, but lessons have been learned, and it is well to remember that advancements have been made. In spite of this, however, the rate of progress compared with what needs to be done is extremely slow. We tend to speak rather vaguely about under-developed territories, and Mr. Faunce, of F.A.O., gave me this definition : " An under-developed area is a region in which, for a variety of reasons, it has not been possible to apply practical and advanced technology which would enable the fullest economic utilisation of the resources of the area."

Of course, everything is relative ; areas like Australia and Canada have vast untapped natural resources, but we do not normally think of them as under-developed since they are associated with a high standard of living. These countries can obtain capital for development. Other areas afford a low standard of living, but it is difficult to envisage further developments, because at present they seem to have no natural resources worth talking about. This would apply to many of the desert and semi-desert areas in the world.

We really associate under-developed areas with a fairly high population and a low standard of living. Although we often think in terms of Africa and Asia, these conditions are also current in Europe as well as South America. It is all a question of degree.

Where there is death by starvation, there is usually over-population, and the only solution would seem to be some sort of industry. The work of the agricultural engineer would seem to lie in these under-developed areas where land is not in dire shortage, but living standards low enough to reduce the expectancy of life.

In considering the problems of introducing machinery to backward areas, one needs first to consider the kind of life the peasant farmer is living. The pattern is very similar for many parts of the world. The farmer will probably live in a one-roomed hut. There is little furniture. When it is cold a fire is made in the room. In some cases smoke is also required to keep out the insects. The human occupants put up with the smoke as the lesser of two evils, but it affects the lungs and eyes. Water is drawn from a well or water-hole which is also used by the domestic animals and is probably polluted. He probably has a light meal in the morning, drinks water or gruel during the day and has a main meal at night. In between growing seasons he probably goes hungry, especially if the rains are late. In some societies the women help with the farm work, and it is useful to have several wives. In some cases there are also draught animals, but a vast proportion of the world's population depends purely on man's own labour. It is only after the farmer has grown his staple food that he can devote some of his time to growing cash crops. In order to sell that crop, he probably has to carry the produce on his head several miles, and then, because he is illiterate, he probably gets under-paid at the buying centre. It is against that kind of background that one has to consider the introduction of machinery.

## The Need for Machinery

Why is the introduction of machinery essential ? It is essential, firstly, because it is only in exceptional circumstances that man by his own efforts can produce more than an existence living. Secondly, in the tropics the human body is less efficient because of the heat. Thirdly, many of the peoples of the under-developed countries already have their stamina undermined by disease, so they have a low work capacity.

Full mechanisation requires the following essential conditions :

Roads, or some means of transport.
Education and training facilities.
Repair facilities.
Land preparation.
Social adjustment.

The first four ingredients require capital investment ; the last—social adjustment—requires the willingness and ability of the people themselves to accept changes, and the detrimental effect of general illiteracy amongst a people cannot be over-emphasised.

Although mechanisation of agriculture has made rapid progress in this country in the last twenty years, it is interesting to consider that the main essentials for the use of machinery, even down to the drainage of land, had taken place over the previous century. It is difficult to give a priority rating to these essential conditions, though my personal opinion is that roads are by far the most important factor in any agricultural development.

Mr. John Mayne carried out a survey and wrote a Paper for the Institution of Agricultural Engineers on

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* *Massey-Ferguson (G.B.) Ltd.*

transport of crops in Colonial Territories, and it is worth noting that a considerable proportion of cash crops start their journeys to the world markets as head loads. Most bullock carts and donkey carts are still too expensive to be owned extensively, and, of course, in many areas bullocks and donkeys cannot survive. From my own experience, I know the difficulties of operating mechanised schemes without roads. Apart from the difficulties occasioned by mechanical breakdowns, there is not much point in growing crops if, after the harvest, produce cannot be transported cheaply.

The bicycle has probably been the greatest piece of mechanical equipment introduced to many backward areas, and it would add vastly to further development if every village had a road capable of taking some sort of three-wheeled carrier cycle.

**Peasant Farming and its Machinery Requirements**

Indeed, when writing this Paper I found it interesting that on a subject of mechanisation I should think in terms of cycles. It is the sort of attitude which is quite common. After something like twelve years of post-war attempts at introducing tractors and machines to Africa and similar territories, the general emphasis is to think in terms of improved hand tools and simple processing machinery.

At the present time there certainly is a need for these. There is a need for a hand-operated diaphram-pump with cheap delivery pipes to replace the traditional shadoofs for irrigation. Apart from being more efficient, the pumps could be moved along a stream bank so that a larger area could be irrigated without the need to construct open channels, which, in addition to being laborious to make, absorb a large proportion of the water when the flow is for a short period in the morning or evening only.

In East Africa there is a need for a small universal drier which could be used on cash crops such as coffee. There would seem to be a place for the development of ox-drawn equipment such as planters, mowers and carts.

The need and market for such small items is growing. For instance, in Northern Nigeria there are hundreds of hand-operated ground nut shellers in use. The use of these machines has improved the quality of the shelled kernels to a state far superior to anything which could be achieved by the traditional method of pounding by mortar in pestle. There are many rise hullers in operation.

Although there is a market, it is essential that the machine or equipment be designed for the territory and the conditions. A few years ago nearly all the corn was pounded and laboriously ground by hand. Now hundreds of small plate mills operate, but because the need is for a flour mill, the owners of the machines succeed in wearing out the plates at a very high rate. It is essential for manufacturers to keep abreast of the use of their products and to review possible modifications or new designs to meet the market requirements.

As in most things, the N.I.A.E., the backbone of British agricultural engineering, has helped in developing machines for this peasant kind of agriculture. A small rice thresher is one example.

Expensive failures with machinery has caused most people to think almost entirely in terms of small processing machines within the capacity of the small peasant farmer. The next step in this line of thinking is a small tractor to suit the small patches of farms.

The Japanese seem to have some success at home and in other countries in the Far East with small tractors. Small two-wheeled machines can be useful for paddy cultivations and on some plantations, but in my opinion their application must be extremely limited in under-developed territories. My primary reasons are these :

Firstly, where the main consideration in their use is low capital cost, then it is extremely difficult to engineer a machine to meet the arduous conditions of half-cleared land and rough handling by inexperienced operators.

Secondly, many small machines, although they enable a man to do five times as much work, also cause him to put in twice as much physical effort himself in order to operate the machine.

However, nothing static—trials are still going on in East Africa, and if experience eventually enables satisfactory machines to be developed, then a major achievement will have been made.

**Information Needed for Basic Implement Design and Development**

The present emphasis on hand tools, small processing machines and animal draught implements is the natural development of people who have been involved with mechanisation in the under-developed territories and who have experienced some of the frustrations and failures of post-war attempts at rapid mechanisation on a large scale. In the immediate circumstances ,of course, this kind of development in mechanisation is the only one which can be applied extensively. In East Africa the average yield of cotton is about 300 lb. per acre, and in West Africa it is about the same. It does not give much scope for mechanisation when the cotton only brings sixpence a pound or £7 to £10 per acre gross. On this basis the use of expensive machines is hopeless ; if, however, the yield is 1,000 lb. per acre the situation is improved and, in fact, considerable increases in yields can be achieved. The increases are not made overnight, but by slogging, hard research work. It is essential, however, that the ultimate use of machines for planting —and more important, harvesting—should not be overlooked. The problem of increased yields does not, however, lie entirely with the botanists, pathologists and agronomists. It is often overlooked that the availability of mobile power alters the whole concept of farming and agriculture.

The basic requirements of any plant are sunlight, soil nutriments, air and water. Sunlight is beyond us, but, given the information, more could be done about controlling water and air for the plant. In the past, such research as has been possible in the more backward areas of the world has been based on trying to improve on the peasant methods of cultivation. However, a farmer can only adopt his practice to the implements which he has at his disposal. As engineers, we can learn a great deal from these practices, but what we really need to know is " What are the water and air requirements of the plant ?" and " What is the rainfall distribution and intensity ?" After that we can design implements and work the land to try to achieve the best use of the weather and climate.

In some European areas the rainfall during the growing period is low and a restricting condition for optimum yields. By using tractors and having power and equipment for ploughing deeper than was possible with oxen or horses, the water from winter snows can be absorbed by soil and later utilised by the crops to give substantially higher yields.

In East Africa a system of tie ridging was used to retain water in the ridges to improve the cotton yields. A tractor-mounted implement was made from tie ridges. The N.I.A.E. did a further development of this implement and many members will have seen it. A further development of this system appears promising in West Africa. In Northern Nigeria the rainfall during the main rains is too intense and the soil too impermiable to allow tie ridges to be used throughout the season. The main rains, however, are too short for optimum results to be achieved with the cotton. By co-operation between the cotton research workers and agricultural engineers, it was possible to make a deep cultivator, almost a two-row sub-soiler, to be used in the dry season so the initial rains can be absorbed. During the main rains the ridges run freely, and then towards the end of the rains ties ridges can be used to hold the water in rows. The effect is to extend the growing period available to the plant.

Very little is known about the air requirements of the soil, though work is being done at the N.I.A.E. We know it is important for successful plant growth. It is especially important in areas of intense rainfall and strong sunshine for the soil readily caps,, not only increasing the hazards of erosion, but also limiting water penetration and soil aeration. If one can measure " tilth," one can design towards the best means of achieving it.

A great deal has been written about scheme failures. As engineers, we must admit that, although not the main cause of failure, mechanical breakdowns have been contributory factors. In British territories many of the tractors and implements were designed to meet British home conditions. In some cases, machinery was used in a way which the designer never envisaged. There was a make of plough which suffered bent axles, but most of the damage was not done in work but in dragging the ploughs scores of miles across country in the normal season's operations. In other cases, designers did not anticipate the affect of dust and hard land on bearings which normally are expected to withstand mud and water. On the tractors there was insufficient air filtering, and even recently a manufacturer was advising wrong oil for the engines of his tractors. Batteries, too, gave trouble. Six months was the expected battery life for tractors in some conditions. There is very little cooling on a tractor working in dry conditions at temperatures over 100° F. But these are purely development problems which have or are being solved. In some circumstances, American manufacturers were probably more fortunate, in that they have to meet vastly differing conditions in their home markets.

Speaking generally, in the tropics and sub-tropics, when there is sufficient moisture, plant growth is extremely rapid. Implements need to deal with considerably more weed and trash than in the temperate zones, and tractors need to have more ground clearance to enable weeding to continue as long as possible so that the crops can provide sufficient leaf growth to outgrow the weed competition.

Considerable improvements in strength and reliability have been made in the past ten years, and in addition South African-made implements show considerable promise. Again, however, the machinery must be designed to meet the conditions or at least be adaptable to the conditions where limited demand does not warrant a manufacturer starting a full development programme. In this respect, the development of hydrostatic transmissions as has been in progress at the N.I.A.E. is of considerable importance, since it would enable a basic power unit to have greater range of wheel settings and ground clearance than is possible with present-day mechanical transmissions.

**The Need of Land Development**

So far I have largely ignored the economics of mechanisation in under-developed territories. In many cases the economic outlook is very bleak, indeed. The low yield per acre and in many areas the short growing season requiring a high capital investment in machinery for which there is little use during the off seasons make costings very high and profits difficult. If, however, we are inclined to say the situation is hopeless we have only to consider the example of Israel.

On the face of it, there would appear to be three main factors in the rapid development in Israel ; firstly, a great deal of capital has been invested into settlement farms at a low interest rate ; secondly, people have been willing to adjust themselves to a different life in order to try to make a success of the schemes ; thirdly, Israel has been fortunate to have scientists to investigate the various problems that arise and to have engineers to carry out the schemes. In fact, many developing countries now seek the Israeli specialists.

The lessons of the past 15 years are obvious. Mechanisation cannot be undertaken in isolation. The essential conditions for mechanisation, in the twentieth century sense, were quoted at the beginning of this Paper. To implement schemes for achieving these conditions means considerable capital investment. Under-developed countries are under-developed largely because they have not got that capital. The funds have to be given or loaned to them.

We have learned in East Africa and the Americans have learned in their dust-bowl areas that we cannot just rip up the soil with machines and call that farming. On the other hand, those people who think in terms of slow evolution of peasant farming are mentally living in a world which has gone. Improvements in the standard of living in poorer countries is not an academic study—it is very much a question of human squalor and suffering, and in these days the state of affairs in the Congo and China are as much our concern as France was to Britain a century ago. The mechanisation and improved production of peasant farms of two or three acres is well nigh impossible and some sort of collectivisation is essential. In British Colonial territories not much has been achieved in this line, since it is against our policy and inclination to interfere unduly in native traditions. Schemes have been tried, but it is difficult for a foreigner to know what constitutes happy living conditions, and often the land available is only that which has been spurned by local peasant farmers. However, when a country becomes fully independent an elected Government has more opportunity for experimenting on these lines. In Britain the Enclosure Acts resulted in bigger farming units ; in Russia and other Eastern European countries State farms have been established, and Israel has settlements. In new countries, the land was there for the taking. There are various ways of forming workable units for expensive machines.

It is not possible to develop whole areas, but pockets of development can be made in the same way as the profitable Gezira scheme was started in the Sudan. By having all the conditions for full mechanisation in selected areas, the economy of the country can be improved and gradually the circle of development widened. Let me quote a possible example. In Northern Nigeria there are large areas of poor land ruined and over-farmed, but the products of erosion lie in river valleys, including the main stream of the Niger. Whilst there is a land shortage about, in the flood valley there is rich land in the order of 2,000 square miles. Rice is grown in the flood plain and a mechanical unit works there, but because the floods are unpredictable, so are the yields. If the river waters were controlled either by major works on the main stream or by controlling the tributaries, as was done in the Tennessee Valley scheme, not only would it be possible to increase the yields of rice, but other crops could be considered. The essential need for mechanisation is this—that the soils are hard and tough, that temperatures are high, and what can be achieved by manual labour is extremely limited, but suitable machines can work there.

At present water lies over the land when it is time for harvesting, and there is no firm underlying pan, but if the water could be drained off combines could be operated.

By providing high-yielding land, the land shortage around would be relieved and some of the poor land could go into grass and by careful management be improved.

All this needs money, engineering skill and the will of the people.

We must accept that any development means considerable capital investment to engineer the land, to control or distribute water so that agricultural machinery can be operated fully and optimum yields obtained. If that is not done then the best we can do is to try to slowly bring in small machines to assist a peasant farming system.

If, however, development schemes are increased, the need for machinery does not lie only with tractors and implements—the need will also be for large equipment for major projects, smaller machines for making roads and dams, equipment for land levelling and planning. In that way, money is invested into the land for economical farming operations in the years to follow.

Every territory has its own problems, but it can be done, although it is essential that people in the U.K. should remember that agricultural engineering is not fastening a plough on to a tractor. Mechanisation can only be introduced after the land has been engineered and the equipment and machines made for operation in the particular conditions.

Money has been going to under-developed countries at a fairly substantial rate, F.A.O. spends something like 20 million dollars a year, the World Bank has been making loans at an average rate of 400 million dollars a year. On top of this, Britain, Russia and U.S.A. have made their own contributions. British loans, grants and investments to Colonial territories are estimated at £317 million between 1956 and 1958. Under the Colonial development and welfare scheme £140 million are available without any strings attached for roads, hospitals and agriculture for the years 1959 to 1964.

The conditions in under-developed territories have to be tackled with energy and urgency. Recently I read an article by an elder statesman in which he said the problem of an increasing world population was not serious, as scientists could increase yields and if necessary we could irrigate the deserts to grow more food. I think he missed the point—the need for increased food is already with millions of people.

The medical profession in this country has institutions for the studies of tropical medicines and the problems of the poorer countries. Food is the essential to health, and many of the major problems are really agricultural engineering ones. By agricultural engineering I mean engineering applied to agriculture, and we have nothing equivalent to the facilities established by the medical profession. Indeed, after the early post-war years we have now begun to stagnate.

We have experienced designers, civil engineers and research workers, and I suggest the following measures are required to establish our initiative in development work.

Firstly, the major engineering institutions of the country should form teams to study the problems of various under-developed countries and submit specific proposals as advice to the Governments concerned so that they can make application to the World Bank and other sources of funds for these plans to be implemented.

Secondly, funds should be provided so that the N.I.A.E. can greatly extend the work connected with the requirements of under-developed areas.

Thirdly, when the National College of Agricultural Engineering is established, courses suitable for students from overseas territories should be provided, and in my opinion these courses should tend towards the practical and the ability to engineer rather than the purely theoretical.

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# THE HARVESTING OF GROUNDNUTS

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## SUMMARY

THIS Paper outlines the three current systems of harvesting groundnuts—by hand, by lifting and stooking for stationary picking, and by lifting and windrowing for special harvesters. The conditions to which the systems are suited and the advantages and disadvantages of each are briefly described. For many conditions, and in particular for districts where it is likely to rain at harvest time, it is concluded that a "once-over" system, in which the standing crop is harvested in one operation by a single machine, is likely to be the most efficient, with fewer losses in the field. It can also make possible the production of high protein hay from groundnut haulm, which is normally left on the land. Once-over harvesting has the disadvantage that the freshly-dug nuts usually have a moisture content of about 45 per cent. and so have to be dried within 12 hours of harvesting.

A detailed account is given of the development of a once-over harvester suitable for bunch varieties of groundnuts. In the final machine, one row of plants is gathered by two rotary points into a pair of inclined lifting belts, while the tap roots are severed by a share. The plants are first shaken to remove soil as they travel up the belts, and the nuts are then stripped off them by beaters. The clean haulm is discharged undamaged in a windrow behind. The nuts, conveyed sideways from below the stripping mechanism, are cleaned by two sieves and an air blast and delivered into bags. The harvester has proved capable of working at speeds in excess of 4 m.p.h. and of harvesting over 10 tons of nuts in a day.

## I. INTRODUCTION

The groundnut plant (*Arachis hypogaea*) is a member of the leguminosae grown widely in the tropics and sub-tropics as a source of edible oil. When the flowers are fertilised, the stalks or gynaphores on which they grow elongate rapidly until the tips enter the soil, where the nuts develop underground. The total length of the growing period varies with climate and variety and is usually between 105 and 155 days. The mature fruits are capsules containing usually two but sometimes more nuts, depending on variety, with an oil content of 41 to 48 per cent. There are two extreme forms of plant—the bunch and the runner—with many intermediate ones. In bunch varieties, the stems are upright and the mature nuts are grouped round the base. In runner types, the stems are prostrate and, like creepers, run over the surface of the soil, bearing nuts over the whole of their length and hence over a substantial area round the parent plant. In general, the nuts of bunch varieties are produced at the same time and mature evenly ; runners continue to flower as the stems grow, and nuts at all stages of ripeness may occur at any one time. The timing of harvesting is therefore fairly critical, especially with bunch and semi-bunch varieties, if heavy losses from shedding are to be avoided and the full yield of mature nuts obtained. Runners are usually a peasant crop, although they are grown commercially in some countries for the confectionery trade. Bunch or semi-bunch types form the bulk of those grown commercially for oil and, because of their habit of growth, are the more suitable for mechanisation.

## II. EXISTING HARVESTING SYSTEMS

The various ways of harvesting groundnuts at the present time can be grouped under three broad headings. For small areas and under peasant farming conditions, they are lifted entirely by hand and the nuts picked off the plants and shelled or "decorticated" by hand. For larger areas some of the operations are done by machinery, in particular the lifting, picking and decortication. Finally, large commercial growers employ expensive and often specialised machinery to mechanise the whole operation. The divisions between these three systems—hand, part mechanised and mechanised—are not, of course, clear-cut, because simple tools may be introduced for an operation in hand harvesting, and some hand-work may be needed in a fully mechanised system. For convenience, however, they are described under these headings below, and some attempt is made to define how suitable each system is for various types of agriculture under different soil and climatic conditions.

### 1. Hand Harvesting

The groundnut plants are pulled by hand if the soil is soft and wet, or loosened with a hoe or jembe if it is hard and dry. They are shaken to remove any soil adhering to them and stooked to dry out. In dry districts where no rain will fall at harvest and where pests like termites are not serious, stooking can consist of grouping the plants on the ground with the nuts uppermost, or of piling in small heaps. In more humid climates and where rain is expected, the plants are stooked round a single pole or on tripods or tetrapods, often with a frame at the bottom to keep the lower plants clear of the ground (Fig. 1). When dry, usually after three to five weeks, the stooks are pulled apart and the groundnuts

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FIG. 1. Stooking groundnuts.

picked off the plants. Later, at leisure, women shell the nuts by hand and pick them over to make a sample good enough for sale. Simple hand-operated machinery can be introduced into the system particularly for decortication.

## 2. Part-Mechanised Harvesting

As hand harvesting can be regarded as the equivalent of harvesting cereals with a scythe or sickle, part-mechanised harvesting is the equivalent of a system based on the binder. The groundnuts are loosened and

FIG. 2. Digging groundnuts with blades on a toolbar.

their tap roots cut by running a share or blade beneath the row (Fig. 2). They can then be lifted and shaken by hand before stooking, or windrowed by a special machine which picks them up, shakes them and deposits them in a windrow made up of one or more rows (Fig. 3). It is possible, and usually preferable, to combine these two operations of digging and windrowing in the one machine. After lifting, and with perhaps a wilting period in between, the plants are stooked by hand as described above. When dry they are carted to a stationary picker (Fig. 4), or the machine is taken round the field from stook to stook. When the latter method is adopted, the stooks are usually grouped conveniently at a few places in the field. After picking, the nuts are decorticated and graded in a machine of the type shown in Fig. 5.

This system of harvesting has a number of severe disadvantages, the most important being the high labour demand of about 25 man days per acre(1). Hand stooking requires a large labour force, for which there is likely to be little or no demand during the rest of the

FIG. 3. Shaker-windrower.

season and at a time when the native has work to do on his own land. The losses from stooking, caused by moulds, insect and other pests, are likely to be high(2) —up to 40 per cent. in a moist climate. The quality of the sample of nuts produced is often poor, not only because of the damage, but also because the nuts reach high temperatures and low moisture contents when thus

FIG. 4. Groundnut picker.

exposed to the sun and so, during decortication, yield a high proportion of split nuts and nuts on which the skin or testa is damaged. Finally, the cost of providing the 20 or so frames required for the stooking of every acre of an average crop is substantial and is usually an annual charge because they are so readily attacked by termites.

FIG. 5. Groundnut sheller or decorticator and grader.

### 3. Mechanised Harvesting

The methods currently used to mechanise the harvesting of groundnuts are equivalent to the harvesting of cereals with a windrower followed by a combine harvester fitted with a pick-up attachment(3). The plants are usually lifted, cleaned and windrowed by a digger-windrower of the type outlined in Section II (2) above. In some districts—on light, dry soils especially—it is possible to dig the nuts and then windrow them with a side-delivery rake. The crop is allowed to cure in the windrow and is then harvested with a special groundnut harvester or " peanut combine." In such a machine the windrow is gathered by a standard pick-up attachment and delivered to one or more large drums with concaves both fitted with spring tines. Some form of shaker may be used to remove all the nuts from the haulm, which is delivered, very broken, at the rear. The sample is cleaned by a combination of air blast and sieves, often with the addition of stemmer saws. The whole harvester is usually at least as large and expensive as a combine harvester and cannot be used for any other crop. From the harvester, the nuts are decorticated mechanically as before.

This system of groundut harvesting is cheaper for more than about 30 acres(4), but has the disadvantage that it can be used efficiently only in places where the climate is likely to be dry at harvest. If it rains, even larger losses than in stooks will occur in the windrows(5) and the harvesters will not handle green or wet plants effectively. Light soils, too, are more suitable because they permit more efficient cleaning of the plants as the windrows are formed. The capital outlay on equipment is high and none of it can be used for other crops on the farm. With many varieties of nuts, losses too, may be high from shedding in the windrow or during windrowing, and from the pick-up attachment of the harvester. It is a suitable system, therefore, only on large holdings, on light soils where the climate is expected to be dry at harvest time.

## III. A SUITABLE HARVESTING SYSTEM

In order to keep labour demands to a minimum, to avoid losses in stooks or windrows and to ensure a sample of nuts undamaged by moulds, pests or sun, it is necessary to devise a system of complete or " once-over " harvesting. That is, the plants should be lifted, cleaned of soil, and stripped of nuts in one operation. Harvesting would then be independent of weather conditions as long as the land was neither too wet to carry tractors, nor too dry and hard to permit any form of digging blade to enter. The amount of labour required would be the minimum possible and losses during harvesting should be considerably less than with other methods. If possible, there should also be no damage to the haulm, which is green at the time of harvesting, and could become a valuable source of high protein hay in countries where hay is usually very scarce indeed. From the stook or windrow, haulm is often valueless, except in dry districts where stooking is done very carefully and extra labour used in protecting it after picking. Even then the final product is so broken up by the picking process that it is of poor quality. If made from the standing crop, however, it can be as good as lucerne or alfalfa hay with a protein content of about 11 per cent.(6)

Apart from the advantages listed above, complete harvesting of groundnuts has one disadvantage. When the nuts are mature, the groundnut plant is still in an active green state and the nuts themselves contain about 45 per cent. of moisture. In this condition they will keep for little more than 12 hours in sacks or in bulk. They must, therefore, be dried either by spreading them out in the sun or artificially. The latter is likely to be the more convenient method if any quantity of nuts is involved. Recent work(7) has shown that this can be done efficiently and cheaply by simple equipment, which can often be used for drying many other crops. It has been shown, too, that artificial drying gives a much better sample and smaller losses through nuts becoming damaged during decortication.

## IV. PRINCIPLE OF A HARVESTER

In considering the principle of a suitable complete harvester, it can be assumed that bunch varieties of groundnuts are the type that will normally be grown where the crop is to be mechanised completely ; they are, for example, much more suitable for mechanised inter-row cultivation. Accordingly, the problem becomes one of producing a machine that will lift bunch or semi-bunch varieties of groundnuts and deliver a clean sample of nuts into bags or a bulk container. Further, it must do this at a rate which would ensure that the whole crop on a holding, big enough to justify the purchase of a harvester, would be lifted in the normal period of about a month when the crop was ripe.

Since the mature nuts on a bunch variety are usually concentrated round the root of the plants within a radius of about 4 ins., it is undesirable to put the whole plant through a mechanism like a threshing drum. The volume of green material to be treated would be unnecessarily high and hence the mechanism unnecessarily large and expensive. It is better to arrange to treat only that part of the plant which carries the nuts ; for example, by removing the haulm before harvesting and then digging and stripping only that part which remains in the ground. This approach is unlikely to be the best, however, because the collection, cleaning and stripping of so small a part of the plant under all soil conditions cannot be very easy, and the removal of the haulm entails an additional operation. It is better, therefore, to grasp the growing plant by the haulm and so lift it clear of soil which has been suitably loosened. While held in this way, precise treatment can be given to any desired part of it by a mechanism much simpler and smaller than is needed to treat the whole and the haulm is delivered undamaged.

FIG. 6. Complete or once-over groundnut harvester.

A completed harvester working on this principle (Fig. 6) has been developed and carries out six distinct operations. The haulm of a row of plants is collected by two gathering points into a pair of V-belts pressed tightly together. Below the mouth of the belts a blade share runs under the row to loosen the soil and sever the tap roots. The plants, held by the haulm, are carried up by the belts and agitated to remove the soil from them. They are then stripped free of nuts and delivered in a windrow behind the machine. The nuts themselves are cleaned by sieves and an air blast, as on a combine harvester, and elevated into bags or into a bulk container. The layout of the machine is shown diagrammatically in Fig. 7, and a detailed description of it and an outline of the stages in its development are given below in Section V.

## V. DESIGN OF A GROUNDNUT HARVESTER

### 1. Gathering Points

In any machine which harvests a crop by lifting the plants between belts, the efficiency with which the stems and leaves are gathered has a profound effect on the working of the whole machine. With groundnuts, the way that the haulm is fed into the mouth of the lifting belts decides the level at which the plants travel through the machine. This in turn decides the level at which the nuts are presented to the soil-removal and stripping mechanisms and so affects stripping efficiency and the amount of soil and leaf delivered in the sample. For these reasons, the considerable amount of experimental work that has been put into the design of gathering points for groundnut harvesters has proved of value in the harvesting of other crops like potatoes, carrots, turnips and sugar beet.

For gathering points to be effective, their tips should always run just in the surface of the soil. This means that they must either be hinged individually and designed so that each one can rise and fall to follow the surface, or their depth must be controlled precisely from a wheel or skid set very close to them. Further, they should pivot about a point as low as possible to reduce the tendency for them to dig in. In the construction of gathering points for crops like groundnuts which are green at harvest time, it is better to avoid the use of sheet metal. Stems and leaves do not slide easily over a continuous surface and the plants are often dragged forward by such points moving down the row. They are also far more likely to collect clods and stones and guide them into the belts. Points, built up from a

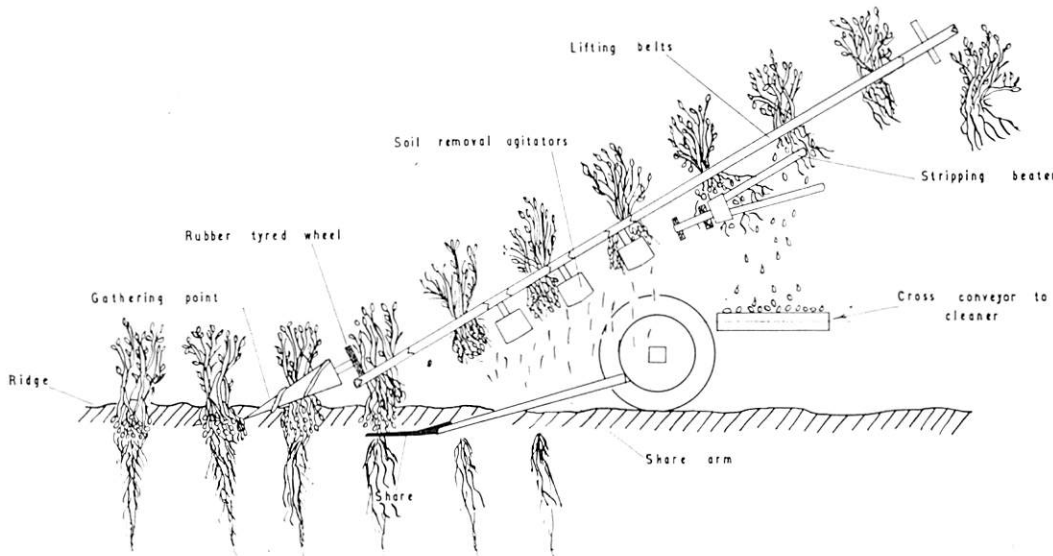


FIG. 7. Layout of once-over harvester.

number of slender rods, welded together at the tip, usually suffer less from both of these disadvantages.

If the crop is of a spreading habit and some of the outside stems are pinned to the ground by the nuts on them or by the passage of tractor wheels, no form of stationary gathering point will be really effective. In such cases, it becomes necessary to adopt a type of power-driven point, which will lift the stems and hold them upright until the mouth of the belts reaches them. A design that can be used conveniently with lifting belts is shown in Fig. 8. The two cone-shaped points are friction-driven by means of small rubber-tyred wheels at the base which are held in contact by springs with the upper surfaces of the two front idlers carrying the lifting belts. The cones each carry ribs in the form of a two-start helix or scroll to grip the plants in contact with them. The rotation of the points—upwards in the centre—ensures that the stems are brought upright, while the speed of rotation and pitch of the helix make sure that the stems remain vertical until the belts reach them.

FIG. 8. Rotating gathering points.

## 2. Share

Unless the land is very soft and moist, it is necessary to sever the tap root of the groundnut plants and to loosen the soil round them before they are lifted out of the ground. If this is not done, a high proportion of the nuts will be dragged off the plants and left behind. The fore-and-aft position of the share in relation to the mouth of the belts is also important. If it is too far forward, plants will be lifted before the share has loosened the soil round them and nuts will be left in the ground ; if too far back, the haulm will not be gathered cleanly. At the ideal setting, the plants, rising in the wave of soil passing over the share, are gripped when they are at the highest point of the wave. In this way, they are lifted out of the ground from below, rather than pulled by the haulm from above. The loosened soil then falls away from the plants as they continue to move upwards in the belts.

The share itself is of the conventional type used in the lifting attachments shown in Fig. 2, but the design of the mounting is important if blockages from weed and other surface rubbish are to be avoided. If it consists of two vertical supports with the share between them, there is a risk that they will collect weed, which will eventually build up into a complete blockage. A more suitable mounting is shown in Fig. 9, where a single member,

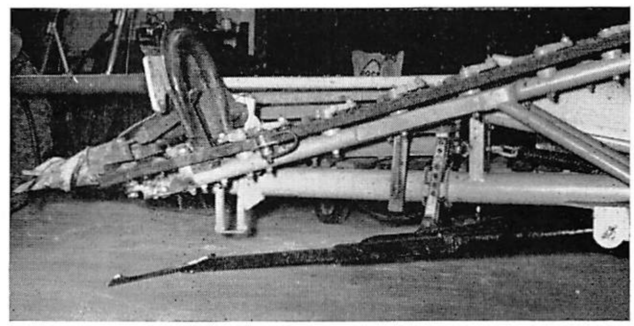

FIG. 9. Share and mounting.

hinged towards the rear of the machine, runs forward so that one end of the share can be attached to it. In this, as with any share intended for use in relatively undeveloped countries, it is necessary to provide some safety device to avoid damage on striking buried stumps, roots or boulders.

## 3. Lifting Belts

The principle of harvesting crops by gripping the tops between belts has for many years been used successfully for sugar beet. The speed of the belts in relation to the forward speed of the harvester is so arranged that individual plants are lifted vertically from the soil. This is especially important with groundnuts if losses are tc be avoided. Too high a belt speed so that the plants are dragged backwards, or too low a speed so that they are carried forwards, will cause nuts to be stripped off the plants and left in the soil. The height of the mouth of the belts should be accurately controlled because it decides the level of which the plants are gripped and hence the position of the nuts in relation to the subsequent soil-removal and stripping mechanisms in the harvester. In practice it has been shown that sufficient accuracy can be attained only by adjustable depth wheels placed as close as possible to the mouth of the pulling belts and attached to the belt assembly, which is so mounted that the front is free to rise and fall in work.

Standard V-belts, carried on pulleys and idlers of standard form, have proved quite suitable for groundnuts. Special belts, with special forms of tread on the gripping surfaces, have shown no advantages. It was thought, in particular, that an interlocking tread, consisting of a single rib on one belt and two ribs on the other, would grip the plants more firmly and prevent stems from being pulled from the belts during stripping. In practice, there was no evidence of this happening ;

in fact, the ribbed belts caused more damage to the stems, weakened them and so led to breakage in stripping. Under all conditions, soil accumulated in the grooves of all the pulleys carrying the lifting belts. When it was wet the soil built up quickly and was reinforced by pieces of leaf and stem ; when dry, dust moistened by plant sap built up more slowly, but formed an accumulation which was a great deal stronger. It is essential, therefore, that all pulleys in this application be fitted with scrapers or are of a type that is open at the base of the groove.

**4. Soil Removal**

On light land in good condition, the groundnut plants receive sufficient agitation as they travel up the belts to remove the small amount of soil adhering to them. In heavy land and under dry conditions substantial amounts of soil will cling to the plants. They must then be shaken in such a way that it is broken up and falls away without carrying nuts with it. The simplest form of agitator is a series of spring tines or flaps mounted alternately on the pulling belt assembly so that the plants, on striking them as they travel upwards, are deflected first one way and then the other. Although such attachments can be made to give agitation of the severity required, they are usually unsuitable because of the way in which they retard the passage of the plants.

Effective agitation must therefore be produced by some form of power-driven mechanism. An eccentric roller, for example, mounted beneath and to one side of the belts, with its major axis parallel to them, can be made to shake the plants effectively, but it retards their progress to some extent and soil builds up on it. A more

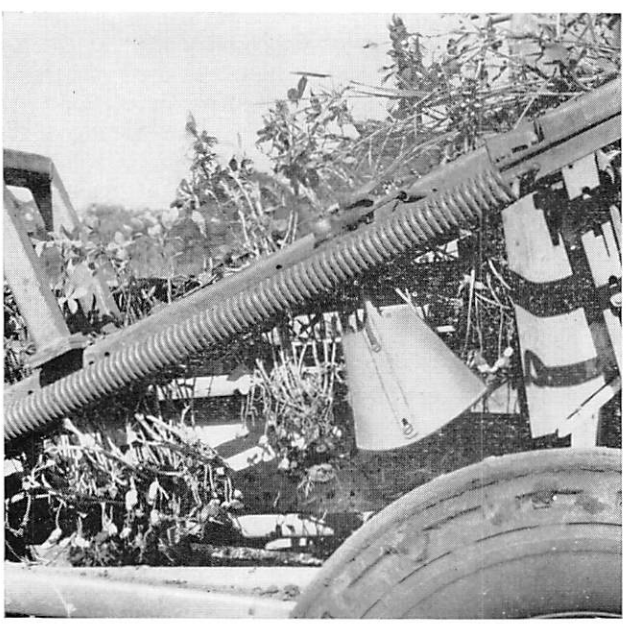

Fig. 10. Agitator for soil removal.

satisfactory mechanism consists of a number of flattened, truncated cones attached to some of the idler pulleys carrying the belts. They project downwards so that their wider parts at the bottom are in the path of the root systems of the groundnut plants as they travel upwards (Fig. 10). Because they are rotating with the pulleys, the surface of such agitators is travelling at a similar speed to the plants and in the same direction, and so does not retard them. When several are mounted alternately below the belts, they merely deflect the plants sharply back and forth. The strength of the blow that each agitator delivers can be varied by making them in two halves hinged at the top, so that they can be opened or closed to adjust their width. Further, if they are made of some strong flexible material like heavy rubber sheet or belting they will flex enough in work to shed any soil that becomes attached to them.

**5. Stripping Mechanisms**

The chief problem in the design of a mechanism to strip the nuts from the clean plants as they travel up the lifting belts is to find one which is severe enough in its action to remove all the nuts, yet does not break up the plants. If the plants are damaged, leaves, stems and roots will be delivered with the nuts and so increase the difficulty of producing a clean final sample. As with soil separation, a stationary device offers the simplest stripping mechanism. A pair of bars, with a gap between them that will not allow single nuts to pass through, can be mounted with their leading ends close under the belts and their rear ends at a distance from the belts greater than that of the lowest nuts. Then, as the plants are drawn through the gap by the lifting belts, the bars will strip off the nuts in much the same way as if the plants were pulled through the hand. In practice, such a method is not suitable because the drag of the bars will often break the haulm or pull it out of the belts and so cause a complete blockage in the machine.

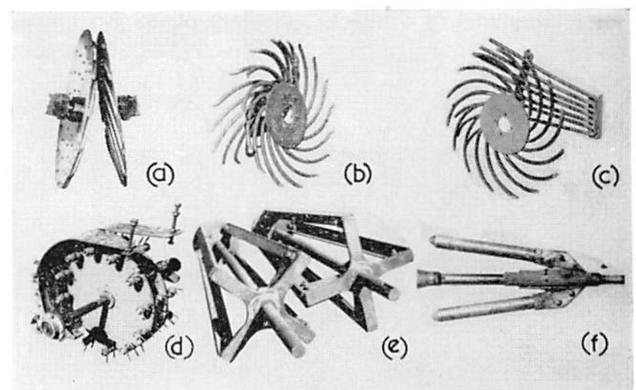


Fig. 11. Experimental stripping mechanisms.
(a) Ribbed discs. (b) Pair of spiders.
(c) Spider and grid. (d) Tined drum and concave.
(e) Four-bar interleaved beaters. (f) Two-bar beater.

Once again, the solution lies with the adoption of some form of power-driven mechanism. In this case it must be one that will strike the nuts at such a speed that they are snatched off the plants without retarding their progress through the machine or imposing too great a load on the haulm and without causing damage to the nuts themselves. A range of the power-driven stripping mechanisms tried is shown in Fig. 11. The pair of ribbed discs (11a), the pair of spiders (11b) and the single spider and stationary grid (11c) were all capable of stripping the plants clean, but suffered from the same defects. The area over which the two working surfaces approached each other closely enough to strip effectively was far too small. This meant that the time available for removing the nuts was so short that severe treatment was necessary to be sure of removing them all in the time available. The discs or spiders had to run at such a speed and the gap between them had to be so close that many of the nuts were damaged and an excessive amount of leaves and stems was torn off the plants. The alternative of a form of threshing drum and concave, of which an example with spring tines is shown in 11d, did not suffer from this fault, but was unacceptable because of others. The area over which stripping could take place was large enough to ensure that all nuts were removed without damage, but the tines on the drum broke up the plants and delivered a great deal of plant material with the sample. Further, the stationary tines on the concave, together with the slit through which the plants had to pass, retarded them and caused blockages in the same manner as the stationary stripping bars.

The most consistently successful stripping mechanism has been a pair of inter-leaved beaters of the type shown in Fig. 11e. Set below the belts with their longitudinal axes diverging from them towards the rear, it was possible to arrange for the area over which effective stripping took place to have any length and depth desired. By tapering the beaters from front to rear, it was further possible to arrange for the stripping to become progressively more severe as the plants passed through. The beaters with four angle bars shown in 11e were much too severe in their action at all settings, and so were replaced by others with two round bars of the type shown in Fig. 11f. These have consistently stripped cleanly under all conditions without damaging the nuts. Provided, too, that the bars were of the correct length and diameter and the beaters were run at the right speed the amounts of plant material delivered with the sample have been small. Once a setting had been found at which the plants were stripped clealy, a reduction in the diameter of the bars and an increase in their length or in beater speed has always led to an increase in the amount of haulm in the sample. The table below gives some typical field results from trials of these variables.

| *Setting* | | *% Haulm in Sample* |
|---|---|---|
| *Diameter* of bars (17 ins. long ; speed, 650-r.p.m.) .. .. .. | $\frac{1}{2}$ in. | 12·2 |
| | $1\frac{5}{16}$ in. | 3·2 |
| *Length* of bars ($1\frac{5}{8}$ in. dia. ; speed, 650-r.p.m.) .. .. .. | 20 ins. | 19·9 |
| | 17 ins. | 7·6 |
| *Speed* of beaters (bars $1\frac{5}{8}$ in. dia., 17 ins. long) .. .. .. | 820-r.p.m. | 11·1 |
| | 650-r.p.m. | 9·0 |

For ease of construction with the limited workshop facilities available at the time, all the beaters tested had a shaft through the centre which was carried in bearings at each end. Haulm occasionally became wrapped round this shaft, and so it would have been better to have used beater bars attached at the front ends only to a short shaft carried in a pair of bearings. Beaters of this type are shown diagrammatically in Fig. 7.

**6. Cleaning of the Sample**

The sample delivered by the stripping mechanism needed further cleaning before it was suitable for drying and storage. As a first attempt, the uncleaned sample was removed from below the stripping mechanism by a pneumatic conveyor with a conventional form of aspirator for separation at the delivery end. Such a system was known to be satisfactory for dry groundnuts in shell, but proved quite unsuitable for freshly harvested ones. However efficient the soil removal mechanism, some particles of soil always adhered to the nuts and were removed in the stripping process. If wet, this soil bound together by leaf and haulm accumulated in the ducting and eventually blocked it ; if dry, plant sap bound the dust together to form a similar build-up. It follows, then, that any suitable system of conveying and cleaning for freshly-dug groundnuts must be capable of handling a proportion of soil, together with the nuts and some unwanted plant material. Conveyors must be capable of passing or shedding soil, and elevators must have buckets perforated or otherwise modified to prevent an accumulation of soil in the bottom.

FIG. 12. Cleaning drum for groundnuts on the harvester.

After the failure of pneumatic conveying and separation, a combination of a cross-conveyor, with $\frac{3}{16}$ in. diameter rods spaced $\frac{3}{8}$ in. apart, delivering into a bucket elevator proved satisfactory for removing the sample from beneath the stripping mechanism. The elevator delivered into a horizontal drum 2 ft. in diameter and 5 ft. 6 ins. long, driven at 38-r.p.m. The first section, covered with $\frac{3}{8}$ in. square mesh, removed soil ; the second, covered with $1\frac{1}{2}$ in. square mesh, passed groundnuts, but conveyed any pieces of haulm over the end (Fig. 12). The first section of the drum proved satisfactory, but in the second the mesh became blocked very quickly with pieces of haulm and those groundnuts which had the gynaphores still attached to them. When the mesh was replaced by rows of curved $\frac{9}{32}$ in. diameter bars, attached by their leading ends only, such blockages were avoided. The drum alone, however, is not the ideal form of cleaning mechanism for this application.

It is bulky and, because of the lack of any form of air blast to remove leaves and other light material, does not produce a sample that is clean enough for drying without further treatment.

Stationary experiments with a conventional groundnut cleaner showed that the combination of two sieves and air blast, as used on combine harvesters, could produce a final sample of the desired purity. A correctly designed top screen was capable of removing any haulm and passing the nuts, the right size of bottom screen would separate the remaining soil and the airblast would carry off leaf and similar light material. When subsequently fitted to the harvester, these components have given similar results in the field and can be adjusted to produce a sample which needs no further treatment before drying and storage.

## VI. OUTPUT OF THE HARVESTER

Clearly the rate of working of a machine of this type will depend very much on the state of the soil and the condition of the crop. It can and has been used at speeds in excess of 4 m.p.h., which, in 36 in. rows, are equivalent to a net rate of work of over 1·5 acres/hour with a single-row machine. In practice, a rate of 5 acres per day should be attainable under all reasonable conditions. In a good crop the harvester will deliver over 1 cwt. of wet nuts in shell per minute and is capable of producing over 10 tons of nuts in a day. Bagging-off and tying at this speed is rather more than can be managed by one man, and it might well be desirable to handle in bulk on farms that could be equipped and organised for this.

## ACKNOWLEDGMENTS

The development of the complete harvester described in this Paper could not have taken place without the help of the Tanganyika Agricultural Corporation under the chairmanship of Sir Stuart Gillett. All the field work was carried out in the three regions, Urambo, Kongwa and Nachingwea, administered by T.A.C. and with the very active co-operation of the regional managers and their staff. Much of the construction of the experimental machines in Britain and their modification and field trial in Tanganyika were supervised by Mr. R. J. Ofield, of the Soil Department of the N.I.A.E.

Further development of the harvester has been carried out by Messrs. Ransomes, Sims & Jefferies, Ltd., of Ipswich, and the National Research Development Corporation, of 1, Tilney Street, London, W. 1, has borne a share of the cost.

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## DISCUSSION

DR. W. D. RAYMOND (Tropical Products Institute) gave some figures for the production of groundnuts. The world trade amounted to some 13 million tons of unshelled material and United Kingdom imports were about 300,000 tons of shelled nuts—about 70 per cent. of the figure for unshelled dry pods. The production of decorticated groundnuts in Nigeria varies, but in 1958 it was 761,000 tons. Gambia exports about 70,000 tons and Tanganyika about 15,000 tons annually. Probably the bulk of the crop for the United Kingdom was of Nigerian origin, most of which was grown on peasant holdings.

If the production in Nigeria could be mechanised by some form of co-operative scheme, Dr. Raymond thought that the machine described by Mr. Hawkins should have a considerable potential. He stressed the drying problem when there were 10 tons of nuts a day containing 45 per cent. moisture.

The drier they had already seen, he continued, was a two-stage one, and he wanted to know the cost of running it. While mechanised drying had advantages, it could be difficult from the costing point of view, because of the low cost of peasant labour in Africa. Sun drying (for example, on polythene sheets) should be seriously considered in dry areas. He had noticed a Hungarian Paper read at Baden-Baden in 1959 describing the drying of oil-seeds by dielectric treatment, and wondered if Mr. Hawkins had any information about this novel method.

Dr. Raymond queried the figure of 40 per cent. losses from moulds and insects, which he thought was rather high. On the subject of decortication, he said that there had been an attempt in Nigeria to introduce large-scale decortication, but now they had adopted small hand decorticators. The introduction of these small machines, combined with a premium for quality, had resulted in the whole of the crop containing a minimum of 70 per cent. whole nuts—a remarkable achievement. For large-scale mechanical decortication it was necessary to ensure that a uniform product was fed into the machine, and this required pure strains of seed. Many peasants saved seeds from the crop for sowing and that did not give uniformity. Therefore, although the machine described was welcome, its introduction in Nigeria might have to be wedded to small-scale drying and decortication. Unless this was done, it would be difficult to introduce it in a peasant economy.

MR. J. E. MAYNE (Colonial Development Corporation) thought that the meeting had been presented with an excellent example of machine development work, and he was grateful to Mr. Hawkins for his clear and concise description of work which had extended over a number of years. Mr. Mayne emphasised the widely-different conditions in which groundnuts were grown and said how interesting would be the adaptation of the machine to wider districts than Tanganyika. He wanted to know more about the power requirements under different soils and other conditions. For instance, the soil appeared to be friable in the photographs shown. Had heavier and wetter conditions been experienced during the trials ? It did strike Mr. Mayne that under some conditions a wheel tractor and power take-off might not be sufficient.

The title of the Paper did not appear to confine discussion to the N.I.A.E. machine in particular, and therefore he would like to introduce a controversial point on yields. The rate of work of the machine per day was not in dispute, but the figures quoted by Mr. Hawkins indicated that an exceptionally good crop had been found on which to conduct trials. A good average yield would be 1,000 to 1,200 lb. per acre, he would have thought. Evidently, in Tanganyika they had been growing four times this.

The machine had been described as working in ridges at 36 ins. spacing. Mr. Mayne was under the impression that it was very important for growers to get close planting to combat " Rosette " disease, and for the same reason some growers delayed weeding as long as possible to increase the humidity around the plants and so discourage insect vector of the disease. Could 36 ins. be safely adopted ? In conclusion, he thought that the meeting had heard a good example of co-operation between the different parties interested in agricultural machinery development, the grower as represented by T.A.C., the engineer of the N.I.A.E., the public through N.R.D.C., and the manufacturers, Messrs. Ransome, Sims & Jeffries, being mentioned in the Paper.

MR. HAWKINS replied first to Dr. Raymond's question about drying costs. The figure in 1958 was about £5·23 per ton of dry kernels by artificial drying. For sun drying, one possibly worked with a $1\frac{1}{2}$ in. layer, which was 60 lb. per square yard, and the crop dried in eight days without stirring. A 3 in. layer would have to be stirred every other day. However, 60 lb. per square yard over eight days might run into acres of drying ground, and although capital costs were lower he questioned if that method was desirable. Dr. Raymond had put his finger on the problem when referring to the sheer amount of water to be removed. If plants were left standing up in the ground for a day or two with their tap-roots cut, it was possible that quite an amount of moisture would be lost before harvesting, and that idea would be tried.

He had no information on the dielectric system of drying. Losses in the field up to 40 to 50 per cent. were based on American figures and conditions in East Africa, but they were not Mr. Hawkins' own figures.

On hand-decortication, he agreed with Dr. Raymond that the smaller mechanical decorticators were very poor machines and needed improvement. With hand decorticators someone's effort was being used, and they were not going to punish the nuts any more than they had to, so it was gentle.

Discussing the place for the machine he had described, Mr. Hawkins said that they had been concerned so far with only part of Africa. But he drew attention to the large areas of groundnuts in South Africa, in the U.S.A., in the northern territories of Australia, and also in Israel.

The mechanism of the machine needed about 7-h.p., plus the power requirement for pulling one share through the soil. As most tractors would pull two blades, he said he would not expect a normal one to have any difficulty with the single-row harvester. They had worked under much wetter conditions than shown and had worked in Africa when no other machine could do so. Also they had operated in very hard conditions.

The figure of 10 tons of nuts was for those wet in shell, so Dr. Raymond's sum was wrong. About closer planting and " Rosette " disease, he mentioned the introduction of resistant varieties. Nevertheless, they were not confined to 36 in. rows, for it was only a matter of wheel settings, and they had worked down to row widths of 20 ins. and on twin rows at 36 ins.

COL. P. JOHNSON (Roadless Traction) said that he had come to the meeting because of an interest in Nigeria and the groundnuts that were produced there. Was it not a fact, he asked, that the nuts produced in Nigeria were produced by peasants using hand methods and operating on fragmented land ? He referred to the scheme of the Sudan Gezira Board, which was applied to land occupied by peasantry who lived on the verge of starvation the whole time, and it had depended on a good rainfall whether they could feed their children. But in a few years of the commencement of that scheme what had been those miserable peasants were allotted land within that scheme and, in so far as they went to work at all, went in motor cars ! He did not see any difference between groundnuts in Nigeria and cotton in the Sudan Gezira, and did not see why that sort of scheme could not be applied in Nigeria. Could Mr. Hawkins give him any indication if there were any possibilities of this ?

MR. HAWKINS' answer was that he thought that if the social problem could be overcome a scheme something like that of the Sudan Gezira could be used. However, in this he was liable to get on to one of his hobby horses. In Tanganyika, T.A.C. was trying to develop some sort of tenant farming scheme, but there were still the social problems. In places where holdings were small and the land fragmented, the line that mechanisation must take was not the development of specialised machines costing very little, but rather the correct planning of the way that the whole countryside was laid out so that standard machines could be used efficiently. Mechanisation could come through a government contracting service, but he saw no future in that. Then there were the people who said let the small farmers co-operate. But he saw little future in that either, because farmers did not co-operate well, and if equipment was co-operatively owned it meant that no one owned it—so no one looked after it.

The brightest idea was on the lines of the village contractor. The right man should be taken from a village and trained on the equipment he was going to use. Then he should be allowed the equipment on easy terms and sent back to the village. With responsible supervision during the first stages he might turn his village into an efficient unit.

LT.-COL. W. N. BATES, having stated that he had been in the position of a government contractor with the Bombay Government, then agreed with Mr. Hawkins' remarks on contracting services.

American figures for yields which were a little out of date, said Col. Bates, were that in the best conditions 1,500 to 2,000 lb. per acre might be obtained. In the Transvaal and the Orange Free State yields would be 800 to 900 lb. on average, and in India they could be as low as 400 or 450 lb. That would mean that 10 tons a day would represent in acreage anything up to about 60 acres, and, owing to fragmentation, the number of growers involved might be as high as 20. In India, when trying to bring village co-operatives together for mechanisation, one would probably take about four or five months, and thus lose a season before starting. Social conditions had to be overcome before people could accept new ideas. Before that was done one could not get mechanisation in a big way.

If the machine described was not to remain a dream, he continued, it had to be built on a mass-production basis to make it possible for the smaller or middle farmers to buy it, or it was not worth the manufacturers' putting it into production. The bottle-neck did not occur in getting a big enough market to accept the value of the machine.

MR. HAWKINS declared that he seemed to have set everyone on the wrong foot with his figures for wet nuts in shell. In rough figures, the equivalent amount was about 5 tons of dry nuts in shell. Normally, people talk of dry nuts, but he and his colleagues had been speaking so much of harvesting the wet crop that they had got used to quoting wet figures. He said that he would like to think one started by finding a market for a machine like this in areas where groundnuts were grown in large units and went from there to the contractor who could cope with the small men. It had been the same story for the combine.

MR. G. HENNIKER-WRIGHT (Ford Motor Co., Ltd.) referred to Mr. Hawkins' statement that it was essential to have the plant facing slightly backwards on entry between the belts and observed that a requirement for this must be a careful co-ordination of speeds on the machine. For that reason, he asked, would it not be better to have a separate engine? Another question from Mr. Henniker-Wright was: What is the durability of the machine?

MR. HAWKINS' reply was that in determining the speeds of the mechanism, what one did was to calculate as though there was no wheel slip. In real life the slip that did occur provided that little difference that allowed the plant to face backwards. He did not know the life of the machine and was not going to guess. Although there were no accurate figures, the life of a pair of belts was about 50 to 60 acres; if they were set correctly, the wear was not great.

MR. D. JOSSAUME (Saffron Walden) described his experience when travelling through Africa on sales from 1948 to 1958. It had been a practice in introducing mechanisation in West Africa to pick out in various villages people with money who could do contracting. But this work was retarded by the Department of Agriculture, for it had asked his concern not to introduce mechanisation in this way through individuals until the country had gained sufficient agricultural engineering knowledge to put the machines they had received into work in a way which would not be detrimental.

MR. BUSH (Ghana) said that he had spent nine years in West Africa and agreed that the mechanisation had been retarded by the Department of Agriculture. He referred to the soil erosion problem in that area.

MR. A. NOBLE (Unilever, Ltd.) reminded the audience that the bulk of the cultivation of groundnuts in Nigeria was of a peasant nature. Women supplied the cultivation and it was a free service, so mechanisation would have to be paid for. He asked if there was any reason for moving the trials from the Kongwa to the Urambo area. His recollection of using a disc plough in the Kongwa soils was that they were very abrasive.

MR. HAWKINS explained that trials had started at Urambo. They then went to Kongwa, but there was no rain and no nuts, and so they were transferred to Nachingwea. On the machine the share lasted about a year. On the question of abrasive soils at Kongwa, he said he was pretty sure it was the choice of the wrong implements that was responsible for this experience, for the Kongwa soils should never have been ploughed with disc ploughs.

THE PRESIDENT underlined the importance of the groundnut as a crop, and said that the development of the machine described was a good example of the work of the N.I.A.E. People would have said 10 years ago that the production of this machine was not possible, but the end product they had seen in the film was only a forerunner of something that was to come.

Down the line somewhere, said the President, his own industry had to come in. Last year in this country his industry provided special solvents, not only for groundnuts, but for the recovery of the oil. Although these solvents were expensive, industry consumed no less than 4,000 tons of them. The Institution was grateful, he concluded, to have provided a platform on which this Paper could be discussed.

# ELECTIONS AND TRANSFERS

*Approved by Council at their Meetings on 22nd November, 1960, and 24th January, 1961.*

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# FORTHCOMING MEETINGS IN LONDON AND BRANCHES

1961

MARCH 6TH

Three Papers by Members of the West Midlands Branch.

MARCH 13TH

Annual General Meeting, Northern Branch.

MARCH 14TH

" Procedures for Sprayer Testing," by P. Hebblethwaite, B.Sc. (Agric.), N.D.A., M.S. (Agric.Eng.) (Mich.), A.M.I.Agr.E., and P. Richardson, N.D.H. London.

MARCH 14TH

" Animal Environment," by Dr. D. W. B. Sainsbury. Western Branch.

MARCH 16TH

Discussion—" Agricultural Machinery on the Farm." Scottish Branch.

MARCH 22ND

" Spraying and Dusting Machines," by R. J. Courshee, B.Sc. East Midlands Branch.

APRIL 17TH

" Hydraulics," by D. G. Booth. Western Branch.

APRIL 25TH

**Annual Meeting** (A.G.M., followed by Conference and Dinner), 10 a.m. at Piccadilly Hotel, London, W. 1.

## APPOINTMENTS SERVICE

An expanding agricultural machinery manufacturing company which at present manufactures in Western Europe a range of equipment well established in the British market, and which will soon undertake production in England also, requires a Sales Manager, preferably 30 to 35 and with a knowledge of the home market, to be responsible for all aspects of sales, public relations, advertising and servicing. The same company also requires an Assistant Production Engineer, preferably under 30, with recognised qualifications in engineering and agricultural engineering.

Further details of these posts, and the current list of appointments in agricultural engineering, may be obtained from the Secretary.

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Messrs. Bamfords, Ltd., of Uttoxeter, Staffs., invite applications from members for the post of Agricultural Machinery Designer. Applicants must be of at least H.N.C. standard and have had some experience in this field. The appointee will be able to produce original ideas and to develop established ones.

Further details from the Secretary, Bamfords, Ltd., Uttoxeter, Staffs., quoting reference A.R.9.

# IN THIS ISSUE




HEPWORTH & CO.
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:: LTD. ::