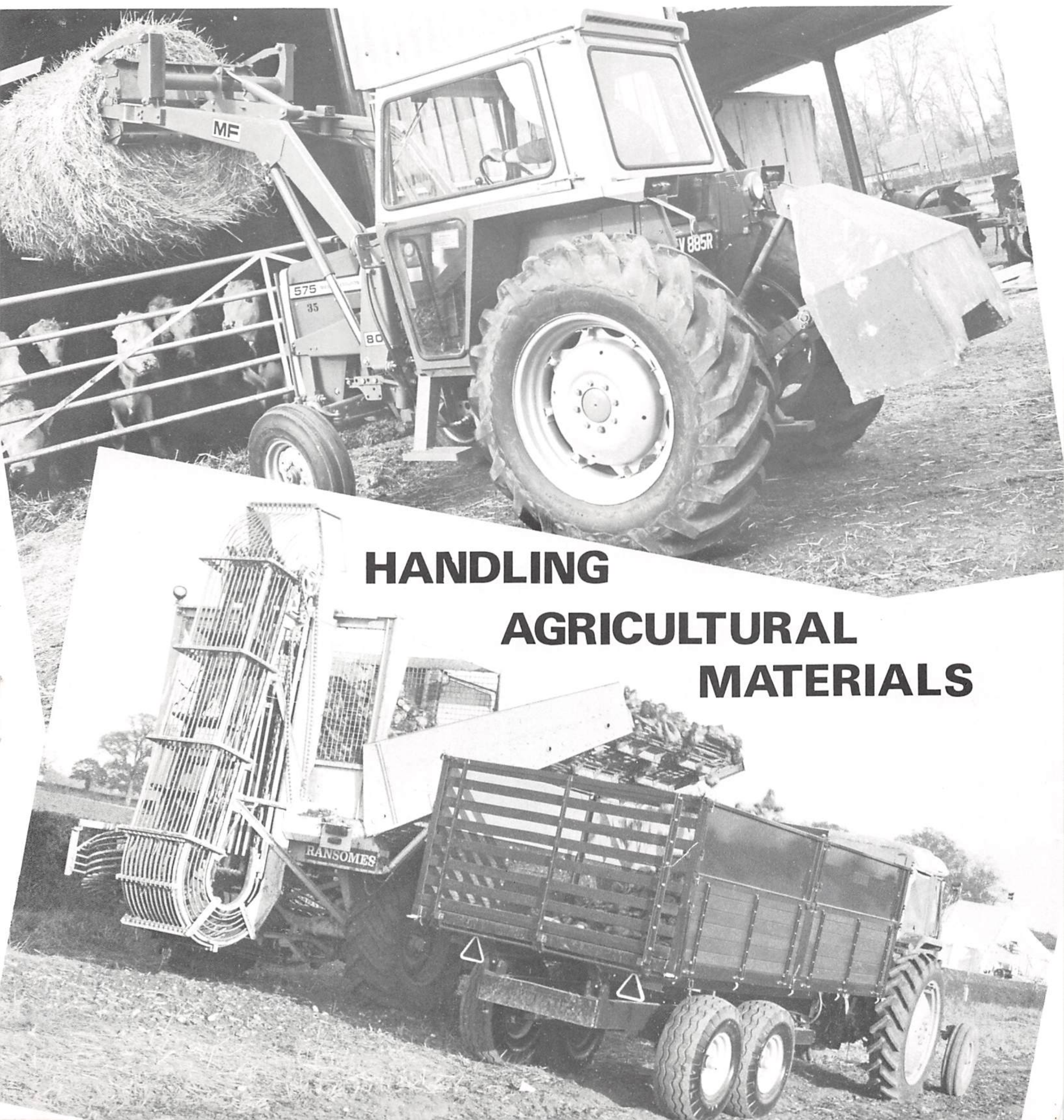
THE AGRICULTURAL ENGINEER

JOURNAL and Proceedings of the INSTITUTION of AGRICULTURAL ENGINEERS ISSN 0308-5732

Volume 33 Autumn 1978 No 3



HANDLING AGRICULTURAL MATERIALS

THE
AGRICULTURAL
ENGINEER

ISSN 0308–5732

JOURNAL and Proceedings of the INSTITUTION of AGRICULTURAL ENGINEERS

Volume 33 **AUTUMN 1978** **No. 3**

The AGRICULTURAL ENGINEER is published quarterly by the Institution of Agricultural Engineers West End Road, Silsoe, Bedford MK45 4DU

Tel: Silsoe 61096

ABC
MEMBER OF THE AUDIT BUREAU OF CIRCULATIONS

Price: £2.00 per copy, annual subscription £8.00 (post free in UK)

CONTENTS

Front cover pictures. Top — Handling a big round bale. Bottom — Sugar beet handling.

The Institution today and its future

J C Weeks, President IAgrE

WHEN I was asked to set down my thoughts and ambitions for the Institution during my period of Presidency it seemed appropriate to begin by referring briefly to the progress made by the Institution since the extraordinary general meeting held in July 1973. This was to approve the Council Working Party recommendation of the reorganisation of the Institution's activities.

It will be remembered that this working party was born out of the then critical position of the Institution; its remit was to carry out a fundamental review of the organisation and to make recommendations to Council for its future development. The speed and accuracy with which the members of the working party diagnosed the problems confronting the Institution and quickly recommended effective solutions deserves the appreciation of us all, for they provided the foundation on which the current success of the Institution is built. Similarly, thanks are due to Council who, under the guidance of respective Presidents, took the necessary action to implement the recommendations and also to the membership who gave their full support to the changes proposed.

As a result we have a growing membership and one prepared to assist with and participate in Institution activities, as is shown by the success of conferences organised both nationally and by branches. The Institution finances are also in good shape owing to the increased membership, the success of conferences, an efficient administration, improved sales of the Journal and advertising space and by increasing members subscriptions. No one likes to raise subscriptions and successive Presidents have given detailed explanations why it has been necessary to do so. All I would add is that each increase was kept to 10% during a period when inflation ranged from over 25% to never less than 15% and when services to members were being substantially improved.

No organisation can operate efficiently working from hand to mouth and it was essential that the Institution should be put on a sound financial footing. This has now been achieved but it is equally important that the improved position should be maintained in the future.

I would now like to refer to the Council of Engineering Institutions (CEI) and the Engineers Registration Board (ERB). The former was established in 1965 by Royal Charter with sole powers to designate corporate members of constituent member bodies as Chartered Engineers. This Institution made an early approach to CEI seeking affiliation and you will now have seen that Her Majesty the Queen was pleased, at the meeting of the Privy Council on 31 May 1978, to approve the grant of a Supplemental Charter to Council. What this means, among other things, is the admission of approved non-chartered engineering Institutions as Affiliate Members of CEI with the right to sponsor, for Chartered Engineer registration, individual corporate members who have the required qualifications.

The application for Affiliate Membership of CEI made by the Institution in 1977 in anticipation of the new arrangements is still under consideration but it is hoped that a favourable decision will be announced shortly. It will then be necessary to wait for CEI to set up the administrative arrangements for the operation of the Chartered Engineer register and to issue details of admission requirements for CEng registration.

Affiliate Membership of CEI will be a tremendous step forward and of significance not only to those corporate members who have the necessary qualifications but to every member of the Institution. It should also help in recruiting new members since applicants so qualified will recognise that they can obtain CEng status through the Institution of Agricultural Engineers.

Meanwhile, the Institution, as a constituent member of the ERB, continues to sponsor Members and Technician Associates as Technician Engineer (CEI) and Technician (CEI) respectively and to build closer ties with the Board. To this end Mr Colin V Brutey is Deputy Chairman of the Technician Board, Mr Martin G Clough is a member of the Technician Engineer Board and has recently joined the Qualifications Committee and Mr R W (Bill) Ladbrooke – Chairman of Western Branch – although not representing this Institution, is Chairman of the Technician Engineer Board. Thus by maintaining and indeed increasing its links with

CEI the Institution is in a better position than ever before to ensure that the voice of agricultural engineering is heard in appropriate discussions and fora in CEI.

I see as an important responsibility during my term of office the need to continue the work of past Presidents to further the standing and influence of the Institution in the wider world of engineering – a world which is under scrutiny at the moment. Having given our evidence we must now await the findings and recommendations of the Finniston Inquiry and the subsequent decisions of Government. Already there are various inspired reports of the radical measures the committee considers should be taken if the profession is to play an important role in the regeneration of British industry and the creation of wealth.

The history of engineering in Great Britain – not least of agricultural engineering – is second to none and will not be found wanting in the future. Clearly, there will be new challenges in the next decade including the need to harness new sources of energy and to meet the required standards of health and safety to safeguard not only the operator but also members of the public.

If engineers are to achieve the status and respect they seek from a society which seems to give them little credit, they need to close ranks and counter with supporting evidence giving their side of the story. This can best be achieved by the engineers joining and backing their respective institutions and those institutions in turn supporting CEI.

To sum up, I see the Institution as having successfully passed through the "survival" stage so aptly described by Mr J V Fox at the start of his term as President in 1974. It is now in a position to consolidate the gains made and to increase and widen its influence in the world of engineering and of agricultural engineering in particular.

But the strength and extent of the Institution's influence is related to the size of its membership. Could I, therefore, end by confirming my intention to do all I can to further the aims and objectives of the Institution and to ask you to show your support by recruiting at least one new member during the year 1978/9. To double the membership in 12 months would be a truly marvellous achievement and one well within our capabilities.

Handling agricultural materials

P L Redman

TO the layman the most apparent benefit of mechanisation is the reduction of physical effort. The fact that this is invariably achieved by improved materials handling is less obvious. Recently, however, this subject has justifiably gained more recognition and established an identity within the range of disciplines encompassed by agricultural engineering.

Every farming and horticultural activity involves the handling of materials — from the picking of lettuce to the harvesting of sugar beet. When accumulated, this is equivalent to approximately 130 M tonnes of materials handled annually in England and Wales, and much of it more than once. This exceeds the quantity handled in any other sector. Furthermore the range of handling characteristics of agricultural materials is enormous, from eggs to farmyard manure.

On the face of it, then, agriculture has the biggest materials handling problem, but is the industry taking full advantage of the handling techniques developed elsewhere? Should other concepts be considered?

At the same time, the United Kingdom may have advantages which should be exploited. For example, the average holding size is greater than in the remainder of Europe, with fewer workers available. In theory, therefore, UK farmers have the greatest need for materials handling systems which should be more highly developed. Can this be turned to export advantage?

Apart from reducing physical effort, materials handling systems can be planned to provide the opportunity for:—

i. Economy in the numbers of workers

ii. Provision of better working conditions

iii. More timeliness at planting and harvesting

iv. More control over the quantity and quality of materials handled

v. Additional processing, as this is often closely integrated with the handling system and cannot be considered independently.

All these can have a marked effect on efficiency of production and overall profitability.

The 1978 annual conference, attended by 200 or so people, was held against this background under the chairmanship of Mr Dick Patrick who has direct experience of all aspects of the subject. The objectives were:—

i. To take stock of current developments and their application in practice, comparing opinions and examining the opportunities for improvement.

ii. To encourage both the agricultural engineering industry and farmers, through publicity of the conference, to consider the topic more frequently.

With these terms of reference and considering the vast range of the subject, it was rarely possible to concentrate on engineering detail. In many ways this conference could be regarded as the introduction to others concentrating on more specific subjects.

In the opening paper, John Holt critically analysed the principles of materials handling as applied to agriculture, and considered the case for developing a vehicle designed specifically for farm transport.

Using their experience as ADAS mechanisation advisory officers, Don Bull and "Nick" Nicholson reviewed current practice as applied to crop and livestock production respectively. Both welcomed the steady developments in mechanisation, and stressed the need to consider farms as units with individual characteristics so that flexibility of application should remain a key feature of future developments.

Jim Avis and Harry Carnall put the manufacturers' view and outlined the constraints to which they are subjected — some of which are remote from the specific requirement of the ultimate user.

Finally, Tony Dumont illustrated the potential benefit of the "systems approach" when applied to this complex, interacting subject.

Clearly, improvements in materials handling have taken place, at a rate dictated by the economics of the industry, and rarely impeded by lack of technology. In future, as complete systems of mechanisation are developed, the materials handling features and their interactions should be given particular consideration.

1979 National Conferences

Spring 1979 (In association with East Midlands Branch).

At the Key Theatre, Peterborough, on Tuesday, 20 March 1979. One day.

Subject: **Mechanisation in the Production of Vegetables for Processing.**

Annual 1979

At the National Agricultural Centre, Stoneleigh, on Tuesday, 8 May 1979. One day.

Subject: **Durability and Wear of Equipment.**

Autumn 1979

At the National Agricultural Centre, Stoneleigh, on Tuesday 9 October 1979. One day.

Subject: **Tillage Equipment Design and Power Requirement in the Eighties.**

This Conference is being organised by the Royal Agricultural Society of England, in association with the West Midlands Branch of the Institution.

* * * * * * * * * *

Details will be published, and registration forms distributed, as and when information is made available.

All enquiries concerning Conferences should be addressed to:

Mrs Edwina J Holden, Conference Secretary,
The Institution of Agricultural Engineers,
West End Road, Silsoe, Bedford MK45 4DU

Telephone: Silsoe (0525) 61096.

Materials handling in principle

J B Holt

Summary

A SERIES of questions is posed which, when answered for any particular handling situation, will help in the selection of a good handling system.

Introduction

Since moving materials on farm very rarely improves their value, invariably involves expensive equipment and uses time and fuel, it is a job to be considered carefully. It is pertinent, therefore, to pause and ask why materials are handled and how this should be done. This questioning approach has been followed throughout this paper with an attempt to provide some of the answers. Some apparently puerile questions have been included to complete the logical sequence.

Why and how?

Why do we need to move materials?

The nature of agriculture is such that materials are moved for use in the field or by animals, for storage, treatment, processing or for sale. The sites of production, ie the field or animal housing, storage and utilisation are often at different locations. Exceptionally some useful work can be performed at the same time as materials are moved, for example by a cleaner-loader.

Where should crops be stored — close to where they will be required next or near to where they have been grown?

Store management, the need for an electrical power supply and crop rotations favour the siting of stores at the farmstead rather than close to the points of production or consumption. In practice therefore, it is necessary to spend time transporting a crop as it is harvested, which is a period of peak labour demand.

What factors influence the optimum positioning of a store?

The effect on the farm transport and handling system, ie the distances involved, the tonnages, the road conditions, the justifiable or necessary trailer or vehicle size and the labour available at peak times.

When farm transport depended on the horse, grain was stored in the sheaf in ricks close to both the field and a road or in a conveniently placed rickyard. Nowadays the combine produces grain which may require drying and cleaning which can be most conveniently undertaken where electricity is available and close to the farmhouse. The larger capacity of modern tractors and trailers has eased transport at harvest time although the trend towards larger farms has increased the average journey distance.

What is required of a farm transport and materials handling system?

The ideal system must be able to move the complete range of materials about the farm with the minimum of physical effort within the constraints of time, labour and economics determined by the farming system.

A variety of basic transport methods is feasible:—

1. Equipment which functions only for transport, being loaded and unloaded by hand, with a tractor-mounted front loader or by conveyor from a harvester or store, (eg a tractor drawn four-wheeled trailer or non-tipping lorry).
2. Tractor and trailer or lorry with tipping body loaded as above but able to unload some materials which are free-flowing and not sensitive to damage, such as grain or chopped forage by tipping.
3. Handling in unit loads (size or weight less than a full trailer load, eg ton boxes, large bales), by tractor and trailer with loading and unloading by separate equipment such as rough terrain fork truck.
4. As above but transport by self-loading attachments on the front and/or rear of a tractor.
5. By special self-loading trailer, eg the Farmhand big-bale trailer and the New Holland Stakliner.
6. By special trailer with discharge to suit particular needs, eg moving floor spreader, potato trailer, slurry tanker.
7. By self-propelled machine with built-in handling facility, eg fertiliser spreader with hydraulic crane for loading mini-bulk bags.
8. By trailers able to load on to themselves, tip or off-load bodies, prefilled skips or equipment, eg the Fahr system.
9. By self-propelled skip handling vehicles which are not yet available in an agricultural form.

J B Holt MSc(AgrE) BSc(Tech) MIMechE MIAgrE, National Institute of Agricultural Engineering, Silsoe, Bedford.

Paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The National Agricultural Centre, Kenilworth, Warwicks, on 9 May 1978.

What is the requirement for transporting materials to or from field machinery?

The common criterion is that a field machine such as a harvester must not be stopped due to inadequacies of transport but this calls for a general excess of transport capacity, owing to variations in transport distance and rate of harvesting. Delays for loading (load transfer) are accepted for drilling and fertiliser spreading, but should this be so, or could delays also be acceptable in harvesting?

As a compromise, to avoid this occasional surplus of tractors, trailers and their drivers, trailers may be parked conveniently for filling from harvesters with hoppers.

Regardless of what form the equipment takes it must be able to travel to wherever the field machinery requires it and ideally without causing excessive soil compaction and wheel ruts.

What improvements are possible?

Improvements in overall performance may be possible by:—

1. Increasing the travel speed on the land and/or road
2. increasing the size of each transport unit
3. speeding up loading and unloading operations
4. reducing the number of men and machines needed to complete a cycle, eg by eliminating the need for separate loading or restacking equipment
5. avoiding the need for the transport capacity to be matched (with the inevitable requirement for excess capacity) to harvesting machinery output, eg by creating a break-point between the harvesting and transport by skip or unit load handling methods
6. eliminating the requirement for separate field and transport equipment, eg by designing the transport equipment so that it can be used efficiently for spreading the fertiliser, drilling the seed, applying the spray materials, etc, which it has also transported to the field
7. reducing traction problems in difficult soil conditions, eg at potato harvest, by driving all the wheels of the transport vehicle
8. reducing soil compaction and rutting by using high flotation wheels on the transport equipment, by improving manoeuvrability and by eliminating separate loading machinery where possible.

What are the relative merits of increasing load size or travel speed?

Large trailers offer an advantage in some situations, for example servicing two or more combines working together. However, there is less merit in servicing a single combine with a very large trailer, attendant tractor and driver, as most time is occupied waiting in the field. Similarly, unloading may be extended so that the unit is away from the field for a greater time than with a smaller trailer.

Obviously a higher travel speed combined with quicker unloading reduces this time and hence increases the radius at which a given number of transport units can operate without delaying the harvester. The current legal speed limit of 20 m/h on the road closely corresponds to the maximum safe speed for present tractor-trailer combinations. Major changes to this equipment or a switch to self-propelled vehicles are likely to be necessary if higher speeds are to be attained. →*page 68*

Studies by Elliman (unpublished) drew attention to these factors affecting the ability of a transport and handling unit to match a combine's performance:—

1. Distance from harvester to store
2. capacity of the transport unit
3. combine work rate
4. tank capacity of the combine
5. area to be harvested
6. transport speed
7. transport's unloading (turn round) time.

Critical combinations were determined where, with conventional equipment, it would be necessary to introduce an additional transport unit into the system. Higher travel speeds and the creation of a break-point between harvesting and transporting were shown to be the ways of reducing the numbers of men and machines required in a range of circumstances.

How can both turn round time and dependence on separate materials handling equipment be reduced?

Interchanging trailers at one or both ends of a journey may be a way of reducing turn-round time but at present this involves connecting hydraulic and electrical services by hand. Demountable load carrying bodies, equivalent to the refuse handling skips used on some road vehicles, may be more attractive but the equipment so far offered in this country has not been taken up. Probably the operational advantages in respect of a straight forward transport operation have not been seen to justify the extra cost and weight of the special trailer. The practical difficulties of accurately reversing a trailer on wet or rutted surfaces in order to pick up a skip must surely be considerable. The tractor which is used to tow a trailer can be equipped with a front loader so that it can load the trailer itself, but unhitching and rehitching is not always attractive. Hydraulic cranes mounted on the rear of a tractor avoid this but problems of reach or load size dominate then become critical.

What are the possibilities and benefits of combining field machinery with transport?

This combination is a feature of a well known trailed fertiliser distributor which has a built-in powered scoop for loading from a heap. The principle of self-sufficiency could be applied to other activities such as drilling and crop spraying, especially if the vehicle had the facility to offload part of its transport load before travelling on the land. Since this principle may reduce the time available for the field operation it is important that the handling and transport part of the cycle is as efficient as possible.

The interaction between farm transport, materials handling and field equipment is such that developments in one part could have a major influence on the other. For example it has been suggested by two combine manufacturers that the grain carrying capacity (ie the tank) on a combine should be eliminated or greatly reduced since the large tanks of high capacity combines necessitate expensive framework, wheel equipment, transmissions and engine power. Such a change might be possible with a unit load handling system (magazines of large bags?) or a slave transport unit running behind or alongside. The general purpose farm transport would be required to have compatible handling facilities.

What about the problem of travel over variable and sometimes difficult ground conditions?

For economy in equipment and power the aim should be low unladen weights and to obtain good traction all wheels should be driven. This points to a four-wheel drive load carrying vehicle with "agricultural" speeds and specification rather than those appropriate to motorway use. The operational requirements discussed above could be achieved if the vehicles could interchange bodies and handle demountable skips and other load carrying units but to be effective such a system must be convenient to operate and manage. At the National Institute of Agricultural Engineering we shall be examining the possibilities of self-propelled equipment and determining the performance in relation to the mechanical complexity and possible prices of vehicles based on existing mass-produced components.

Materials movement in and around buildings

There is a number of conflicting factors concerning this part of materials handling. Site conditions sometimes make access difficult or it may be that financial considerations limit the area of concrete around buildings. Covered space is relatively expensive so the working space for mobile handling equipment is generally restricted.

What does this mean in terms of equipment?

Good manoeuvrability with minimum overall dimensions are called for but a reasonable load of dung, silage, grain, etc is required. This generally means that equipment for use inside farm buildings will be different from that used for field transport. Equipment which is to operate entirely on hard surfaces can have small wheels which would be useless on the soil, whereas low pressure tyres for the latter surface tend to be bulky and inconvenient in restricted spaces. Saving building costs by restricting the space available for handling equipment may be false economy as it could lead to extra expense in equipment and floors. For instance the wheels of a 'warehouse' type two tonne fork truck can impose higher loadings on the floor than does a large lorry.

Fixed conveying equipment

What is the place for fixed conveying equipment in buildings?

Conveyors and elevators tend to be less versatile than mobile handling equipment, they can not always be used for such a wide range of materials in a given situation and they are not readily adapted to suit changing requirements. The handling system in the buildings needs more careful planning than perhaps is the case with mobile equipment used outdoors.

The feeding of the conveyor and the delivery of material from it probably call for more detailed attention than does the conveyor itself. A decision has to be made about the control or regulation of the flow. Some conveyors such as augers meter materials into themselves whereas others, such as most bucket elevators, will block if supplied with an uncontrolled flow of grain. Generally it is necessary to ensure that there is a continuously clear delivery space otherwise the material will build up and choke the conveyor. Sooner or later trouble can be expected if the feeding and discharge conditions are under the control of a worker who has other things to attend to. In principle a flow sensor and control for the inlet and, or, a level sensor beyond the outlet are required but attention should still be given to the procedure for clearing a blocked conveyor. A steep gravity chute is the most reliable form of conveyor!

Rail mounted travelling gantries of six to ten metre span, similar to those which are being developed to aid materials handling and the mechanisation of crop production under glass, could perhaps find a place in agriculture. It is possible that they could be used to build up layers of large bales on a drying floor and handle unit loads of potatoes or fertiliser, etc, in and out of stores with access from only one end.

Ideally the equipment would be designed into a new building.

Handling materials in unit loads

What are the advantages and disadvantages of unit load handling methods over systems for loose bulk and 'man sized' units?

For this purpose a unit load is defined as items so grouped together or material in a container of such a size to form a load which can be handled by a machine rather than a man.

A unit load would generally weigh upwards of 250 kg (5 cwt) and examples are groups of conventional bales, large bales, pallet loads of bags of fertiliser, mini-bulk bags of fertiliser, "ton" boxes of potatoes, and bulk bins of apples.

What is sometimes called "material management" is facilitated; it is generally easier to keep an eye on the quality of materials in unit loads and also to know what quantity is to hand. The storage buildings do not require pressure resisting walls and can be general purpose structures. Losses due to spillage or contamination are less and one type of handling machine, perhaps a tractor with a fork lift attachment, will be suitable for a wide range of materials stored in similar forms of unit load.

The disadvantages can be delivery and despatch of goods from or to premises where suitable handling equipment is not available and the cost of the pallets or containers. The more widespread the use of certain unit loads becomes, the greater will be the advantages to farmers. Since many farmers could only justify one piece of equipment for handling unit loads in and around buildings with another machine for field use, the problems which arise when one or the other is out of action are important.

Handling materials in unit loads is much quicker than it is by hand methods and it also provides a way of creating a break-point between an operation such as potato harvesting and transport to a store. This can reduce the maximum demand for labour and increase management flexibility.

Materials handling in practice - Crop production

D A Bull

Summary

SOME current answers to the time consuming problem of material handling in crop production are discussed, from fertiliser and seed to the harvested product.

Introduction

Materials have been handled in agriculture since the time man first began growing his own food and it is only during the last 50 years or so that powered machinery has been adopted to reduce the work load associated with handling crops and commodities on farms.

Even so, it is suggested that agricultural engineers have devoted less effort to this subject than to any other aspect of farm mechanisation. However, times are changing and most farmers are now aware that time devoted to handling materials is unproductive and they are keen to consider improvements. Efficient handling methods help to achieve the advantages of timeliness and improve the productivity of each worker employed. Farm workers certainly welcome the use of machines to reduce the physical effort and drudgery which was once accepted as a necessary feature of their work. It is often apparent to them that their neighbours who are employed in factory-based industries work less hard because, in most factories, the concepts of materials handling are already applied.

Handling materials in the agricultural industry is a complex subject. Not only do the materials being handled have a wide range of handling characteristics — oil seed rape, grass, sugar beet — but the day-to-day handling tasks are dependent on the seasonal requirements of individual crops, soil conditions and the weather.

There is a wide distribution in the size of holdings in England and Wales (table 1), and there are large differences in the types of enterprise being carried out on these holdings. Also, each farmer will have his own ideas on how best to finance each enterprise and the number of workers he needs to employ. There are other differences between farms which influence materials handling strategy, notably field sizes, topography, transport distances, farm layouts and designs of buildings. This being so, each farm must be treated as an individual case.

Table 1 Distribution of holdings and crops and grass area by size groups.

Size of holding	*Percentage holdings*	*Percentage crops and grass*
(Hectares)		
Less than 30	56.6	13.1
30-99-9	31.4	36.6
100-299.9	10.4	34.5
300-699.9	1.4	12.3
Greater than 700	0.2	3.5

Total holdings = *201 376*
Total area crops and grass = *9 552 223 hectares*

(MAFF Agricultural Census England and Wales 1976)

Farm buildings play an important role in this subject. Although many outdated buildings remain, most modern crop stores and livestock houses are designed to provide good access and adequate manoeuvring space for handling and transport vehicles.

D A Bull NDAgrE TEng (CEI) MIAgrE, Agricultural Development and Advisory Service, Liaison Unit, Silsoe, Bedford.

Paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The National Agricultural Centre, Kenilworth, Warwicks, on 9 May 1978.

On a national scale, the total time and energy devoted to handling farm materials is considerable. In England and Wales there are some 56 million tonnes of arable and horticultural crops harvested annually (table 2) and most of these are handled at least 3 times before they are finally processed. Each year, our livestock consume about 9.5 million tonnes of compound feeding stuffs and produce at least 57 million tonnes of manure inside buildings. There are also about 3.5 million tonnes of bagged fertiliser delivered to farms annually (Green, 1978).

Table 2 Tonnages handled annually average for England and Wales

	Million tonnes
Agricultural crops	
Cereals	12.25
Silage	11.64
Straw	8.49
Hay	6.19
Sugar beet	5.62
Potatoes	4.44
Fodder roots	2.54
Peas, beans and oil seed rape	1.07
	52.24
Horticultural crops	
Vegetables in the open	2.96
Vegetables under glass and mushrooms	0.26
Fruit	0.51
	3.73
Miscellaneous materials	
Housed livestock manures	57.59
Compound animal feeding stuffs	9.56
Bagged fertiliser	3.50
	70.65

Handling farm materials is a wide ranging subject and it is only feasible in this paper to select a few crops and commodities to illustrate handling methods. The practical aspects of handling fertiliser and some of the more prominent arable and horticultural crops are therefore discussed.

Handling fertiliser

Desirable features of a fertiliser handling system are that the fertiliser is applied at the optimum time (usually autumn or spring depending on the crop), the material is evenly and accurately distributed and because spreading is going on at busy times of the year, the labour requirement ought to be minimal.

Most of the fertiliser used in England and Wales is packaged in 50 kg sealed polythene bags. These are usually transported on pallets by road and rail from the factories where the fertiliser is manufactured to depots located throughout the country. A typical pallet for this purpose is reversible, with plan dimensions 1525 x 1225 mm to carry 30 bags. The fertiliser may be handled into farm stores on pallets but this depends on individual requirements. About one third of all holdings receive less than 30 tonne of fertiliser annually, so for these it may be uneconomical to adopt palletisation.

Some farmers purchased their first fork-lift equipment as a result of incentive schemes offered by fertiliser manufacturers. The use of pallets reduces much of the physical effort which is required to off-load and stack individual bags (table 3) yet the advantages of the bags are retained, such as a wide choice of easily selected compounds and recognisable weights of each.

→page 70

Table 3 Labour requirements to handle bagged fertiliser
(Man minutes per tonne)

Task	*Manual*	*Palletised**
Offload delivery vehicle and place in farm store	6 to 7	1.5 to 2.0
Load trailer from farm store	10 to 12	1.0 to 1.5
Fill spreader	10	10

**Dependent on driver skill and the suitability of the store for fork-lift operation.*

The cost of handling fertiliser once it is on the farm is low compared to the cost of the product, and this commodity provides a good example to show how farmers are prepared to invest in handling equipment not necessarily for economic reasons but, in this case, to reduce the amount of manual lifting which would otherwise be required.

On large farms it would be convenient to handle fertiliser in bulk, but modern fertilisers, particularly those with a high concentration of nitrogen, form a crust on the surface when stored in a heap and the resulting lumpy material is difficult to spread.

A recent development has been the introduction of intermediate bulk containers (IBC) for handling fertiliser. The fertiliser is packaged in a sealed polythene bag which is placed inside an outer 'sack', typically dimensioned 1.0 x 1.0 x 1.4 m and weighing 0.75 to 1.0 t. These sacks have loop handles to enable them to be lifted with a crane attachment and the contents are emptied by slitting the bottom of the polythene inner when the sack is suspended.

Experimental workers in Sweden have reported that the labour requirement for filling spreaders from large bags can be reduced to almost 1/3 in comparison with filling from 50 kg bags on a trailer. (SIAE 1977).

A problem faced by those companies supplying fertiliser in mini-bulk bags is how to ensure that the bags remain safe. For this reason at least one company is operating with non-returnable bags which are destroyed after once used.

The 'big-bag' handling system is particularly applicable to contractors who provide a "deliver and spread" service. The trend is for contractors to use self-propelled spreaders. These spreaders can travel quickly between farms and are designed to operate on soft surfaces.

Spreading fertiliser from the air is also a contractor operation which provides a useful alternative when soil surfaces are unfit to carry land vehicles.

Manual handling is avoided if the fertiliser is in liquid form. Liquid fertiliser accounts for about 10% of the straight nitrogen market in this country. Farms using liquid fertiliser have storage tanks to hold at least 1/3 of the annual requirement, and the applicator is usually hired. Farm staff need not be involved when the supply lorry arrives at the farm to fill the tank, and when the liquid fertiliser is transferred to the applicator it is pumped at about 450 litres/min. Disadvantages of the liquid system are the need for storage tanks and the lower concentration of nutrients per tonne handled, compared to 'solid'.

Handling combinable crops

Cereal grains and other combinable crops are free flowing and usually they need to be dried to a safe storage moisture content following harvest. There are now five or six well established methods of drying and storing cereals.

The tasks associated with these crops include handling the seed at drilling time, transport of the harvested material from field into store, then after storage, movement out of store for processing on the same farm or into bulk grain lorries for road transport.

In recent years there has been an increase in the area of crops drilled in the autumn with the result that on some farms there is a very heavy workload during September and October. For this reason some farmers are seeking ways of reducing the time taken to fill corn drills but unfortunately the long narrow shape of most drill hoppers does not suit bulk handling techniques.

At harvest time the transport of grain from the combine to a store is organised so that the combine is not delayed, and the time available for a trailer to be absent from the field is usually about 15 minutes depending on the combine's harvesting rate and the capacity of its grain tank (Bull, 1977).

The time to unload a grain trailer at the store can be minimal if a run-over pit is provided.

Conveyors which are used in grain stores have a reputation for being efficient and reliable. Most new stores are designed for throughputs of at least 30 tonnes/h and problems associated with noise, vibration and dust can be taken into account at the planning stage.

Equipment used for handling cereals in stores includes:

1. Bucket elevators:

   Bucket elevators are installed as either single- or twin-leg units, and a typical model is 20/20 providing 40 tonnes/h output and requiring about 3.5 kW to a vertical height of 9 m. Output depends on the capacity of each bucket, the bucket spacing and belt speed.

2. Chain and flight conveyors:

   Chain and flight conveyors running in an open trough operate between the horizontal and slopes of about ten degrees. Conveyors with outputs approaching 60 tonnes/h are available. A typical power requirement for an output of 35 tonnes/h over 30 m is 2.5 kW.

3. Flat belt conveyors:

   These are used for conveying horizontally at high outputs over distances up to about 40 m. Output depends on the width of the belt and belt speed. This type of conveyor is reversible and the power requirement for an output of 35 tonnes/h over 30 m is about 5.5 kW.

4. Augers:

   Augers are popular because they are simple, versatile and relatively inexpensive. The output from an auger depends on its diameter, the angle at which it is set to work, and the moisture content of the material being conveyed. Augers longer than about 5 m are usually mounted on a mobile trolley and these can be used with a hopper or collector at the base. Typical power requirement for a 125 mm diameter auger, 6 m long, is about 2.5 kW delivering 20-30 tonnes/h.

5. Mobile grain loaders:

   One make of mobile grain loader uses an enclosed chain and flight to convey grain at about 35 tonne/h. A feature of this loader is that special traces can be fitted to minimise damage to peas and beans.

   General purpose rubber belt elevators are suitable for conveying grain in some situations and these give outputs of between 40-60 tonnes/h.

6. Air sweep floors:

   A convenient method of unloading grain bins is air sweep floors. The floors are designed so that the drying air passes through specially shaped louvres. When emptying is in progress, the air flow directs the grain towards outlets in the floor. A similar principle is used in on-the-floor grain stores and the above-floor air lateral ducts are equipped with suitably shaped air outlets which direct the grain to floor openings along the line of the main duct.

7. Pneumatic conveyors:

   The advantages of using pneumatic conveyors in grain stores are that they provide flexibility in the choice of a route, the grain can be conveyed vertically and horizontally in the same duct and maintenance requirements are minimal. However, sucker/blowers are relatively expensive and the power requirement is high. For example 27 kW to convey grain at 16 tonnes/h through 3 m of suction and 40 m of delivery duct (NIAE, 1969).

   Pneumatic conveyors which are designed for delivery only, use a cell wheel to introduce the grain downstream of the fan. These have an output of about 1 tonne/h for each kW when conveying over a distance of about 20 m.

8. Tractor bucket:

   Some on-the-floor grain stores, particularly those with below floor level air ducts, can be conveniently unloaded using a bucket mounted on a tractor or fork truck. Loading performance is influenced by manoeuvring space and the capacity of the bucket. Grain buckets range from about 0.5 to 2.0 m^3 (0.3 to 1.5 tonnes of wheat) depending on the size of the 'tractor' to which they are attached.

From a farmer's point of view it is likely that handling grain will not present problems provided that the system of harvesting, transport, drying and storage is well thought out before new equipment is purchased. The planning stage includes anticipating requirements up to ten years ahead, attention to details such as good control over the drying process, the ability to separate grains (or oil seed rape) into parcels, ability to clean and weigh, and the ability to handle into and out of store at a fast rate.

Handling bales

Unlike grain, hay and straw will not flow when dumped in a heap. These are relatively light-weight crops and both will deteriorate if left unprotected from the weather.

Most of the hay and straw produced in this country is handled in bales dimensioned 0.46 m wide x 0.36 or 0.40 m high x about 0.97 m long, weighing 19-24 kg. (MAFF, 1977). In this form, the bale is a man-handable unit.

The tonnage of hay to be handled from each hectare depends on the season, but can be 4-5 tonnes. The hay making season extends over six to eight weeks. On some farms hay bales will be moved to a barn for artificial conditioning. (Shepperson, 1971). Distribution of the bales for feeding will normally be to animals housed adjacent to the storage barn.

Straw yields vary from 2-3 tonnes/ha depending on the cereal variety. In most seasons the straw is fit for baling over a period of about 24 days. Straw is less valuable than hay, although there is interest in using it for industrial purposes in addition to its traditional place on the farm for bedding, feeding and crop protection.

Several bale handling systems have evolved over the years and the system chosen for a particular farm will depend on the tonnage of material to be handled in the baling season, the labour force, the uses for which the hay or straw are required and the amount of capital available for investment in bale handling equipment.

There are bale handling systems to handle individual bales and there are systems which require the bales to be grouped into vertical or horizontal stack formations. These stacks can be made by hand or by an accumulator towed behind the baler.

Equipment used to transport the bales from the field include tractor mounted bale carriers, trailed bale carriers and farm trailers. Transport speeds when hauling the bales from the farm typically range between 1.4 and 2.2 m/s. Attachments to tractor loaders and fork trucks for handling groups of bales include side gripping and impaler type mechanisms.

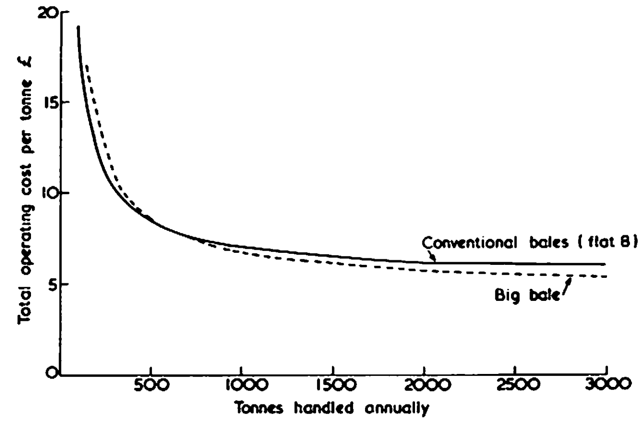
Loading bales into a barn often creates bottle-necks and where buildings do not provide sufficient space for tractor loaders to operate, a bale elevator is used. Stacking with an elevator enables bales to be stacked to the full height of the barn usually 12 to 14 layers high but requires two or three workers.

In any bale handling system the importance of having a compact, uniform bale cannot be over-emphasised.

Balers to make big cuboid or cylindrical shaped bales became commercially available in the early 1970's. These have become known as 'Big rectangular bales' dimensioned about 1.5 x 1.5 x 2.4 m and weighing 300-450 kg, and 'Big round bales' typically 1.7 m x 1.5 m wide weighing about 350 kg in straw (ADAS 1975).

The big bale is a logical development to provide a package which is dimensioned to suit the lifting capacity of a tractor.

Fig 1 Estimated costs to bale and handle straw.



There are less packages per hectare compared to conventional bales and one person with a tractor loader can move them at a fast rate.

Hay in big rectangular bales can be artificially conditioned (Arnold, 1976), but experience has shown that the density of straw in these packages can be 20-30% less than conventional bales of equivalent material.

Big round bales are particularly suitable for handling straw. Their shape provides some resistance to rain penetration and on some farms they are stored outside in single rows until required. When the balers are not stacked they can be handled with a simple attachment mounted on a tractor's 3-point linkage.

In advisory work, for discussion and comparative purposes, it is convenient to synthesise different bale systems using data from surveys and 3 examples are shown in table 4. This type of information can be used to estimate costs. (Howe, 1978) (fig 1).

Table 4 Bale handling — Estimated overall working rates
Man minutes per tonne

System	*Form stacks of vertical 8*	*Load trailer*	*Transport**	*Unload and stack*
Vertical 8 and squeeze loader	8	18	5	25
Flat 8 accumulator and impaler loader	–	16	5	10
Big bale and gripper loader	–	8	6	8.5

**Assumes total transport distance to be 1 000 m.*

It should be borne in mind that in practice, well managed skilled workers can produce bale handling work rates 25-30% above the average (ADAS, 1975). In fact, organised training for those engaged in all materials handling activities on farms is worthwhile, particularly where workers show a natural ability.

Handling potatoes

The potato crop is handled carefully to prevent damage and it is recommended that drop heights should not exceed 225 mm. Timeliness at planting is important and harvesting conditions are very dependent on the weather.

It is convenient to consider the handling requirements of the potato crop under two headings — seed and main crop.

Seed

About 80% of the potato seed for main crop production in England and Wales is not chitted before planting (PMB, 1976) and most of this seed is handled in 50 kg sacks. The work load involved depends on the number of hectares to be planted, but seed in sacks can be palletised.

There is a wide range in the area of potatoes grown on individual farms (PMB, 1976). Timeliness at planting is important to achieve maximum yields and growers aim to plant their main crop over a period of 10-12 working days in early April (Shotton, 1975).

The amount of seed to be delivered daily to the planting field depends on the seed rate and the type of planter employed. Seed rates vary from 2.0 to 3.5 tonnes/hectare. Whereas a 2-row hand operated planter might plant only 1.25 ha in a day, a 4-row automatic planter is capable of planting more than 5 ha.

Handling methods and the choice of seed container are more critical for those farmers who plant chitted seed. The seed is placed into chitting stores from about January onwards.

The traditional chitting store is a glasshouse, but in recent years more use has been made of farm buildings which are equipped with artificial lighting and environmental temperature control. To control the growth of chits on potato seed, the store temperature is held at 3 to 4°C.

Wooden chitting trays, dimensioned 755 x 450 x 165 mm overall and 75 mm deep, holding about 16 kg, are used by the majority of growers. The size and shape of the tray is convenient for a worker to lift and by tradition it is man-handled at all stages. The rate at which tyres are handled can be speeded up and the manual work load reduced if the trays are palletised. Pallets

→page 72

for this purpose carry the tray in layers of four, seven or eight high and these units are stacked inside the store three high.

Handling trays on pallets will not reduce the time spent filling the planter, but this task can be rapid if the seed in the chitting trays is first tipped into a tractor or fork truck bucket, positioned on the headland. In this way the seed can be quickly transferred to the planter. A disadvantage of this system is that the seed is double handled, so the risk of damage to the chits is increased.

Bulk containers

Some growers are seeking ways of reducing the high labour requirement for handling potato seed in trays and there is interest in the use of bulk containers for this purpose. These are satisfactory if the appropriate store environment is provided. Bulk containers already in use are 0.5 tonne wooden, box pallets, typically dimensioned 1195 x 1040 x 882 mm high, 660 mm deep. There are also special purpose box pallets available which are fitted with two or three horizontal partitions to increase the number of seed potatoes exposed to light and air. Ideally, bulk boxes of this type should only be stored in buildings which have refrigerated temperature control.

Another type of container is a 0.5 tonne capacity wire mesh crate. These crates have been developed resulting from work at the Terrington Experimental Husbandry Farm and they have a wire mesh liner which separates the seed potatoes into vertical columns. The crates can be stacked three high, either in a glasshouse or in a chitting store.

The advantages of using bulk containers for handling seed compared to trays are:—

1. They take up less space — 2.5 m^3/tonne compared to 3½-4 m^3/tonne for trays.
2. Less labour is required at all stages — 50 man min/tonne compared to 145 man min/tonne for trays (ADAS, 1977).
3. The planter hopper can be filled quickly, resulting in more hectares planted per day.

Handling harvested potatoes

The potato harvest season extends over about 20 working days, and the tonnage of potatoes to be handled daily depends on the crop yield and type of harvesting system employed. Yields of main crop can vary from 20-40 tonnes/ha, and typical harvesting rates with one-row machines average 0.75 ha/day and with 2-row machines about 1.75 ha/day.

In those areas where casual labour is plentiful some growers prefer to pick the harvested potatoes direct into box pallets. The potatoes are sometimes stored in the same boxes, stacked four or five high, or the tubers may be tipped to a bulk heap. In East Anglia there is increasing interest in the use of 2-row unmanned harvesters. In this case, all the harvested material is transported to the store in trailers where soil, stones and trash are separate from the potatoes before storage.

In any potato harvesting system which transports the harvested crop to a store, the aim is to match the throughput of equipment at the store to harvester output and to have sufficient trailer capacity to avoid the harvester being delayed. Rear tipping trailers in sizes ranging from 3 to 6 tonnes capacity are used to transport the potatoes to a store where they are transferred into an elevator or a bulk receiving hopper. Special-purpose root trailers are used on some farms and these convey potatoes on a belt, running along the bottom of a hopper shaped body, direct to the store intake line.

Grading potatoes out of store is also part of the materials handling exercise. The three types of potato grader most commonly used are: reciprocating grid, spooled conveyor, and endless screen. Farm potato grading lines are usually manned by five to six workers and the average output is about 0.45 tonnes/man hour (PMB, 1976).

Handling sugar beet

Sugar beet is not usually damaged by harvesting and handling machinery but clamps should be protected from frost. The sugar beet harvest extends over a period of between 40 and 60 days, depending on the soil type, although some farmers may wish to clear the fields early, to drill winter wheat.

Again there is a wide variation in the tonnage of beet to be handled on individual farms. Beet yields are from 30-45 tonnes/ha, and the rate of harvesting can be from 1 to 6 ha/day, depending on the type of harvester.

As an example of extremes: a system might use a single row tanker harvester, requiring only one man to operate it, delivering beet direct to a heap adjacent to the growing crop; or it might be a multi-row, multi-stage harvesting system with a team of nine workers delivering the beet in high-lift trailers to a concrete pad 2 km from the beet field.

Usually a farmer will know from experience the number of trailers which are required to transport beet from the harvester to avoid delays, but if a new system is being considered the number of trailers can be estimated from the following equation:—

$$\text{No. of trailers} = \frac{\text{trailer cycle time}}{\text{time to load the trailer}}$$

Trailer cycle time is made up of the time to load the trailer plus the time spent travelling to and from the clamp plus the time spent unloading the trailer.

In recent years there has been a trend towards the use of large trailers for hauling beet — up to 14 t — but because the harvesting season can extend into early winter the heavy loads and wet surface conditions often create traction problems.

Haulage contractors who deliver beet to the factories sometimes also contract to load the beet. They find it beneficial to use high performance industrial loaders with outputs of 80 tonnes/h or more. (Bull, 1976). About 90% of sugar beet is loaded into lorries using tractor loaders or fork trucks, but some farmers still prefer to use slew loaders on a stationery tractor to reduce wear and tear.

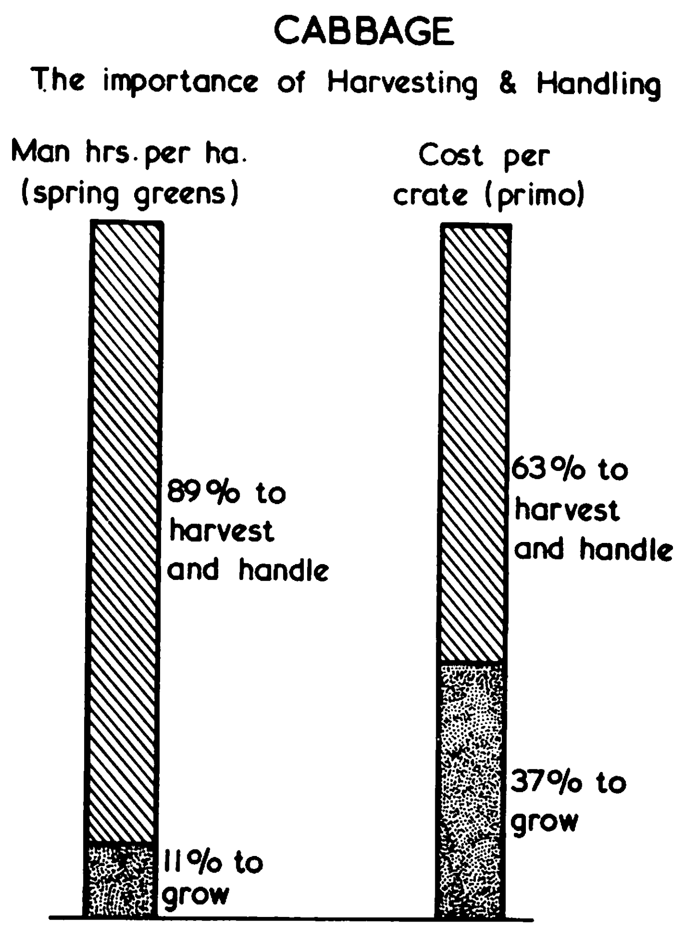
Handling horticultural crops

The handling requirements of horticultural crops are closely related to the ways in which the produce is marketed. By tradition vegetables are harvested direct into market containers, but in recent years there has been an increase in the use of packing stations which prepare the crops for market. Also, a large proportion of vegetables are now grown under contract for processors.

Root vegetables

In practice, horticultural root vegetables are being grown on a larger scale and crops like carrots, beetroot and onions are lifted

Fig 2



Rough terrain fork-lift truck in action.

by harvesters direct into trailers running alongside. Carrots are washed and graded for market immediately following harvest, whereas onions and beetroot can be stored in bulk. Tractor loaders and fork trucks fitted with root buckets can be used to handle these crops to grading lines which are usually housed adjacent to the crop store.

Leafy vegetables

The main feature of leafy vegetables, like cabbages, Brussels sprouts and lettuces, is that the harvesting and handling operations are labour intensive (fig 2).

It has been estimated that at least 3½ million man hours are required to harvest the 17 thousand ha of cabbages which are grown in this country annually. (Bull, 1975). Cabbages do not mature evenly, and for this reason they have to be selectively harvested and the crops are often picked over two or three times. The output from a gang of workers selecting, cutting and 'bagging' cabbages is 135 to 180 kg per hour/worker depending on the maturity of the crop.

Containers constitute a major component in cabbage marketing costs. Depending on the marketing arrangements the containers may be non-returnable skeletal crates, nets or boxes made from card-board, plastic or wood. These are all man-handled units.

On those holdings where the cabbages are transported to a pack-house for grading, they can be handled in box pallets, typically dimensioned 1200 x 1000 x 950 mm high, 735 mm deep. Output from a cabbage grading line, packing to supermarket standards is about 90 kg/h per worker.

When Brussels sprouts are harvested mechanically, they can also be handled in bulk, although most of the crop is still hand picked direct into market nets.

Lettuces are harvested by hand and the heads are normally packed in 18s or 24s into non-returnable crates or boxes at the point of harvest. Mobile harvesting aids are used by a few growers for crops like lettuce and cauliflower. A gang of pickers work along the rows, select, cut and trim the heads and place them on the mobile platform which acts as a packing station.

The major glasshouse crop is tomatoes. Tomatoes are usually picked into plastics baskets, then transferred into market containers called chips which hold about 5.5 kg. The chips can be palletised 70 to a pallet. On a few large glasshouse holdings, and where central grading is practised, the tomatoes are transferred into bulk bins at the glasshouse door for transport to the grading area. (Bull, 1968). Some growers find removal of the plants at the end of harvest a difficult task and a recent development has been the use of balers to bale the material in situ.

A picking procedure similar to that for tomatoes is used in apple orchards. Each picker in a gang, under the supervision of a foreman, hand picks the fruit into a bucket which holds about 9 kg and when this is full the apples are emptied into a bin. Bulk bins for handling apples are limited in depth to about 530 mm to avoid pressure damage. Each bin holds some 270 kg of apples and a skilled picker fills about 3½ bins in a working day.

Self-propelled and trailed fruit bin carriers which self-load and unload apple bins have been developed in recent years. (Bull, 1965). The use of these carriers speeds up transport of the harvested apples from the orchard to the farm. The bins are stacked inside cold stores using fork-lift trucks.

Conclusions

The ways in which farm crops and commodities are handled in practice are closely associated with individual farm requirements. These requirements are dictated by a host of variables, such as the type of farm enterprise, the crops which are grown and the number of workers employed.

The trend is away from man-handable units to handling material in bulk. Where the advantages of handling in small units are undisputed, palletisation is being adopted.

Since the introduction of mechanisation on farms, handling equipment has been developed at a steady pace to meet the requirements of the industry. Due to demands for even higher efficiency in food production, and the need to make working conditions more pleasant, increased attention is likely to be paid to this subject in the future although flexibility will remain the key note.

References

ADAS (1975) Bale handling methods. Farm Mechanisation Study No. 28.

ADAS (1975) Bale handling methods. Supplement to FMS No 28.

ADAS (1977) **Maunder W F.** Potato seed handling techniques. Occasional Notes on Mechanisation. No 264. October 1977.

Arnold R E, Comely D R (1976). Drying large rectangular bales in tunnels, Part 1. NIAE departmental note DN/FC/421/1380.

Bull D A (1975) Cabbage harvesting and handling. ADAS/NVRS/RASE conference. New aspects of cabbage production, NAC, 16 October 1975.

Bull D A (1976). Clamp down on running about. *Power Farming,* September 1976.

Bull D A (1977). Handling combinable crops. ADAS Eastern Region, Cambridge.

Bull D A, Holt J B (1968). Investigation of techniques for handling horticultural produce. Newent, NIAE departmental note 1/MHD/69.

Bull D A, Holt J B (1965). Use of an experimental self loading vehicle for handling fruit. *J Agric Engng Res* 10(1).

Green T L (1978). Private communication.

Howe S (1978). *Power Farming,* April 1978.

Ministry of Agriculture, Fisheries and Food (1977). ADAS mechanisation leaflet No 16 – Balers and Bale Handling.

National Institute of Agricultural Engineering (1969). Test report No 602.

Potato Marketing Board (1975-76) Main crop potato production in Great Britain.

Shepperson G (1971). Future developments in the production and handling of hay. *Journal of Institution of Agricultural Engineers.* 26(2).

Shotton F E (1975). Potato seed handling and planting. *The Agricultural Engineer.* 30(1).

Swedish Institute of Agricultural Engineering (1976-77) annual report.

Materials handling in practice - Livestock production

R J Nicholson

Summary

MATERIALS which are handled in connection with livestock production range from forage and feeding stuffs to waste products in their various forms. Particular attention is paid here to the filling and unloading of bunker silos and to the unloading of slurry compounds.

1 Introduction

1 (i) Scope of paper

As outlined in the previous paper, a vast tonnage of materials is handled annually on UK farms. The handling of materials associated with livestock production can be grouped into three main categories:—

(i) Forage harvested, transported and handled into store for conserved winter feed

(ii) feedingstuffs, both conserved fodder and cereal based "concentrates", handled from store to the point of consumption, and

(iii) waste produced by the stock which has to be collected, possibly stored and then utilised/disposed of, normally by land spreading.

It is beyond the scope of this paper to examine all practical aspects of the above task. Three specific processes of topical interest have therefore been selected for more detailed study taking one example from each of the above groups. These are:—

Filling of bunker silos
unloading of bunker silos, and
unloading of slurry compounds.

1 (ii) General considerations

Very few agricultural materials handling problems are straightforward, particularly where livestock is involved. In providing solutions the engineer has to consider the "flow" properties of the materials involved, any "biological" requirements and in many cases the need for processing or control (eg weighing) concurrent with the handling process. In addition, there will be constraints, to a large extent specific to the individual farm, such as dimensions of and access to existing buildings, amount of capital available, and the degree of operator skill and quality of maintenance likely to be available. A major consideration is the need for an "integrated" handling SYSTEM to perform a number of differing duties — some degree of compromise is therefore inevitable.

It is hoped that the processes chosen as examples will serve to illustrate these points.

2 Filling of bunker silos

2 (i) General

Bunker silos are adaptable to a wide variety of filling and emptying methods, simple to operate, and until recently involved relatively low capital investment. These factors have all contributed to their popularity.

Bunker design varies enormously: settled height of silage achieved commonly ranges from 1.8 m (6 ft) for self-feeding to 3.0 m (10 ft) or more for mechanised feeding. Access arrangements for loading are unfortunately often far from ideal. Thus, easily manoeuvrable equipment is of prime importance. In some cases roofed silos have a low eaves height in relation to the desired settled depth which may limit the dimensions of equipment chosen for loading.

Materials ensiled in bunkers are normally grass mixtures, arable silage (eg cereals) or forage maize, which have dry matter (DM) contents of 18-35%, depending on the maturity of the crop, and the degree of field wilting, if practised. Forage maize is "precision" chopped to less than 12 mm (0.5 in) nominal length. There has been a general trend over the last ten years towards harvesters capable of producing reasonably short chopped, easily handled grass for ensiling: there is still, however a need for equipment to handle grass of up to 150 mm (6 in) length which can be encountered with simple flail harvesters, or loader wagons not fitted with 'extra' knives.

Although dump box/blower systems have been successfully used for filling both conventional and National Institute of Agricultural Engineering flexible walled silos with precision chopped grass, the vast majority of bunkers in the UK are filled using the "wedge" technique by "batch" handling equipment running on the clamp. Alternative types of equipment used for this purpose are discussed in detail below.

2 (ii) Objectives of the bunker filling process

The two main objectives to be achieved are:—

(a) A rate of work equal to or greater than that of the harvesting and transport system. This in turn will hopefully have been selected to suit the tonnage ensiled per cutting cycle, thereby keeping ahead of grass growth and digestibility (Shattock and Catt 1971).

Output required can vary from as little as 6-8 tonnes/hour overall on a small farm up to 60 tonnes/hour for an efficiently organised team based around a self-propelled harvester of over 150 kW (200 hp). The majority of systems are based on trailed harvesters driven by tractors of 45-60 kW (60-80 hp) and likely to produce overall outputs in the order of 12-20 tonnes/hour.

(b) To spread the herbage evenly in the bunker, and provide adequate consolidation to exclude air.

This should achieve the required final density of silage and help ensure satisfactory fermentation. More consolidation is likely to be necessary with long material or herbage wilted to above 25% DM.

In addition the system chosen should be reliable, involve a minimum of labour and either utilise an existing tractor or an alternative power unit which is compatible with other uses on the farm (eg silage unloading).

2 (iii) Equipment available

With the notable exception of rough-terrain lift trucks, the equipment available for clamp filling has changed little in the last six-seven years (Shattock and Catt 1971).

(a) Tractor rear-mounted buck rakes are by far the most popular method of filling bunkers. Introduction of the push-off facility, which gives a positive discharge, combined with the trend to shorter crop material has eliminated the need for manual spreading of grass.

Although tractors as small as 30 kW (40 hp) are employed on this task, for good output more power is desirable, together with rapid 3-point linkage movement and suitable reverse gear ratios. Work rate can then be as high as 25-30 tonnes/hour, given short chopped material, good clamp access and most important, an experienced operator. The use of a 4-wheel drive tractor, if available, will improve traction and stability.

R J Nicholson BScAgric(Hons), Mechanisation Adviser, Agricultural Development and Advisory Service, Bristol.

Paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The National Agricultural Centre, Kenilworth, Warwicks, on 9 May 1978.

Although this equipment is simple and relatively inexpensive, it can be argued that this is a repetitive rearward-looking operation, which makes it difficult for the tractor driver to maintain high outputs for an extended period.

(b) Front mounted tractor buckrakes overcome the disadvantages mentioned above, and allow the operator to place forage into the bunker with more accuracy. It is however essential to use a tractor of at least 37.5 kW (50 hp) fitted with a medium or heavy duty foreloader, power steering, oversize front tyres, and a large counterbalance weight to ensure traction. Outputs of over 20 tonnes/hour are easily attainable.

Front mounted buckrakes can discharge their load by a mechanical trip or by hydraulic push-off/engling. A combination of the latter two facilities gives very positive control of discharge. Hydraulically operated 'crowding' grabs are also available and have the advantage of giving more positive retention of forage on the fork.

(c) "Industrial" loaders with 2- or 4-wheel drive, torque converter or hydrostatic transmission, and a high lift capacity are available in the 45-90 kW (60-120 hp) size range. Potential workrate is 60 tonnes per hour or more with the larger 4-WD models: the majority of farms are only likely to purchase such machines secondhand. Contractors on the other hand often have a sufficient range of work (eg, slurry compound emptying) to justify the purchase of new equipment.

(d) Tracklaying tractors are occasionally used, either with a bucket or earthmoving blade for ensiling material from a high output harvesting team.

(e) "Rough terrain" forklift trucks (RTFLTs) are available in a variety of sizes and forms and have recently come into vogue as a universal handling tool, particularly on arable farms. Their primary advantage is a good lift capacity (normally in excess of 2000 kg) and stacking height of 3.6m+ for precision placement of commodities on pallets. They are often based on proprietary tractor 'skid' units, and gross weight can be in the order of two to three times that of a comparable agricultural tractor due to the weight of the mast assembly and the rear counterbalance weight required for stability.

It could be argued therefore that 2-wheel drive versions of these machines are not suited to silage clamp work, because of sinkage and traction problems. The Agricultural Development and Advisory Service did however record several instances of satisfactory performances from 2-WD RTFLTs fitted with buckrakes working on clamps during 1977, even with relatively long double-chopped material. A minimum engine size of 37.5 kW (50 hp) appears desirable, and it is essential that the slope on the ramp is not too steep (approx. 15^{o}). Output in these circumstances is similar to a rear mounted push-off buckrake on a medium sized tractor, but operator fatigue is greatly decreased, particularly if "torque-converter" transmission is fitted.

Large RTFLTs of around 56 kW (75 hp) fitted with 4-wheel drive and a large fork or buckrake appear capable of sustaining outputs of 40-50 tonnes/hour. Manoeuvrability of some models is poor compared with the 2-WD versions.

It is unlikely however that equipment of this type will be chosen primarily for handling forage — its main justification will be for other tasks involving stacking.

All the equipment described above is capable of dealing with material having a wide range of dry matter content and chop lengths, and will achieve adequate consolidation when filling on the "wedge" principle. It has been suggested in the past that clamps can be filled with batch-loading equipment, such as a high capacity foreloader, without running on the silage surface. A number of instances have been reported of clamp filling from ground level with RTFLT, the process being aptly named the "Wiltshire Wall" or "Cornwall Cliff". Output can be as high as 50 tonnes/hour, even with a relatively low powered truck. For any success with this system of filling however, it would appear essential to ensure short chop length, a maximum of 25% DM, rapid sealing, and preferably 3m+ ensiling height, to help ensure self consolidation and satisfactory ensilage.

3 Unloading bunker silos

3 (i) General

Many practical farmers would argue that the cow is the most efficient method of unloading silage — self feeding certainly offers low cost, reliability and low labour input.

There has, however, been a strong swing to mechanical feeding methods, particularly with larger herds, as these techniques offer opportunities for deeper bunkers, better control of groups of cows and flexibility in siting and width of silos. More recently, the possible benefits of incorporating a number of feeds together in known proportions (ie a "Complete Diet") has been recognised by a number of progressive farmers.

All methods of mechanised silage feeding involve either (a) unloading and transporting batches direct from the clamp to the feed area, or (b) unloading and transfer to a forage box or mixer wagon for subsequent distribution.

3 (ii) Factors affecting choice of unloading system

The main factors to be taken into account when considering various unloading methods are:—

(a) The ability to deal with the chop length/DM % of the silage concerned.

(b) Height of reach of the equipment.

(c) Compatibility with the method of distributing feed and the stock numbers involved.

(d) Compatibility with existing tractors and loaders or alternative power units which may be used for other tasks, and

(e) The need to leave a tidy relatively compact silage face to help minimise the ingress of air and reduce the possibility of silage moulding and deterioration during the feeding period.

The latter factor is difficult to quantify, as the type of forage and its dry matter content have a significant effect, as well as the rate at which silage is used. A nominal rate of progression of 150 mm day into the face is generally considered to minimise such problems, a factor influencing the cross-sectional dimensions of the clamp.

3 (iii) Equipment available

This falls into four main categories:—

Loaders/loader attachments
block cutters
specialised cutter loaders, and
combined unloader feeders.

(a) Tractor loader attachments

Tractor front or rear loaders with fork attachments are available on most farms, are simple, relatively cheap and are thus the most common method of clamp unloading. They are normally used in conjunction with a forage box or mixer wagon although they can be used to deposit silage direct into circular feeders or feed mangers if distance from the clamp is minimal and access is good.

A bunker at least 9 m wide is preferable to give reasonable turning space: maximum height of face which can be dealt with will vary from 3.5-5.0 m depending on the model of loader.

Precision chopped silage can be extracted relatively easily with a standard fork attachment, although some operators experience difficulty in obtaining adequate forkfuls and leaving a tidy compact face. The range of hydraulically operated top grab attachments now available help overcome these problems and also enable tractor loaders to successfully extract relatively long ensiled herbage.

Work rates are well documented (ADAS 1972, ADAS 1977) and are in the order of 7.0 man min/tonne.

An approximate guide to weight of silage unloaded can be gained by tapping a pressure gauge into the loader's hydraulic system. Accuracy is unlikely to be better than ± 6% given careful calibration and operation. Forage boxes or mixer wagons with inbuilt weighing equipment offer the best degree of accuracy available at present.

(b) Slew loaders

Rear mounted slew loaders working from a static position can achieve good work rates (4.5 man min/tonne) and have the ability to work in a relatively confined space. In addition, problems of

→page 76

tractor clutch wear associated with foreloaders are obviated, and this type of machine has the ability to leave a reasonably compact face. Long ensiled materical can be dealt with, although it may be necessary to break up large compact wads of silage so extracted by dropping them on to the bunker floor before loading into the distribution equipment.

Equipment of this type is unlikely to be purchased specifically for silage extraction and must fit in with other proposed uses such as ditch maintenance.

(c) Industrial loaders/rough terrain forklift trucks

High capacity ex-industrial loaders are becoming increasingly popular on larger holdings and have the ability to achieve high work rates (4.0 man min/tonne) by virtue of their large lift capacity. A rough terrain forklift truck fitted with a suitable fork could be used in a similar fashion. The main difficulty with this type of equipment is that its capabilities are easily abused, leaving a mass of silage which has been loosened for a considerable distance behind the actual face, permitting deterioration.

(d) Block cutters

Front and rear mounted equipment for cutting out rectangular blocks of silage have gained rapidly in popularity in the last three years. Many designs originated on the mainland of Europe. An exceptionally clean-cut compact silage face is achieved, and blocks so extracted will keep without appreciable deterioration for a week or more.

Rear mounted machines are either mounted on the tractor's 3-point linkage or on a simplified 'forklift' mechanism, the latter type being capable of dealing with a face 2.5-3.0 m high. The basic design concept is a series of tines which are thrust into the face, the block of silage above them being cut out by a hydraulically actuated blade or a "chain-saw" mechanism. Typical block size is 1.5 m x 1.5 m x 0.8 m, giving a weight of 500-800 kg: a tractor of 37-45 kW (50-60 hp) with good lift capacity is therefore required. Time taken to actually cut out a block is 1-3 min.

This type of equipment can be invaluable for feeding outlying cattle, or small groups of animals in buildings with difficult access: normally blocks are transported by the equipment direct to the feed passage/point of feeding and subsequently distributed by hand. The cutting/transporting operation can thus be limited to one or two days/week if storage space allows. The number of situations which fit the criteria outlined above are however limited, and rear mounted block cutters do not appear to be suitable where forage box/mixer wagon distribution is envisaged.

Several fore-loader mounted machines cutting smaller blocks (of 0.6 x 0.75 x 1.4 m or 0.7 x 0.8 x 1.75 m) are now available. One of these uses two hydraulically oscillated knives as the cutting mechanism. These overcome many of the height or reach limitations associated with rear-mounted models, and can be used for feeding in similar circumstances to those described above.

Some instances have been recorded of front mounted block cutters being used to fill forage boxes: with maize silage, a relatively friable material, little damage to the bed or distribution mechanism is likely to occur. With grass silage, however, it is arguable that this method of clamp unloading is incompatible with subsequent mechanical distribution. Despite this, success has apparently been achieved with robust forage boxes equipped with short tine beaters when handling blocks of high dry matter short-chopped grass silage.

(e) Specialised cutter loaders

Various forms of cutter loader have been designed — only one of these is currently available in the UK. All are based around a cutting head which normally moves down the clamp face in an arc, the silage so loosened being collected and elevated to the forage box or mixer wagon by means of a conveyor or blower.

These machines are single purpose, tend to be permanently attached to the tractor driving them, and are only suitable for use on precision chopped silage. They do however leave a very compact face, and depending on design, can reach silage up to 4.5 m high at an unloading rate of 6 min/tonne or less.

(f) Self loading feeders

A number of machines of this type, most of which are of French origin, are available. Silage is extracted from the clamp by rotating cutters or a hydraulically operated blade and transferred direct into a transporting compartment holding 500-750 kg of silage. Silage is discharged at the feed fence by a cross conveyor or auger. Machines are either linkage mounted, mounted on a high lift frame, or trailed, and height of reach at the face varies from 2-3 m.

These machines leave a tidy compact clamp face, and are relatively manoeuvrable compared with a conventional forage box. Cubic capacity of the machines imported is limited, which detracts from their application where large stock numbers or a long bunker to feed area transport distance is involved. Their relatively high cost is however compensated for by the fact that they perform a dual function. Some problems have been experienced in handling long grass silage with this type of equipment.

These methods of clamp unloading are summarised in table 1.

4 Emptying slurry compounds

4 (i) General

The recent strong trend away from straw bedded yards to cubicles for housing dairy cows has resulted in larger amounts of 'slurry' to be handled for a given size of herd. This slurry, consisting of a mixture of faeces and urine, has a dry matter content ranging from 10-13% and as such can vary from a 'thin' to a "thick" porridge-like consistency: it is neither true solid nor liquid. Addition of waste water will give a pumpable consistency; drying out or addition of straw bedding or waste feed results in a solid or semi-solid material handleable by bucket or grab.

The handling properties of slurry are therefore difficult to predict. Problems always arise when a system designed to handle solid material becomes too liquid or vice versa.

4 (ii) Objectives/methods of storage

Storage of slurry is desirable, particularly with a larger herd, to minimise damage to land by wheeled traffic in winter, to obviate the daily chore of spreading, and hopefully to gain better utilisation of the valuable plant nutrients available in this "waste".

Two basic long term (ie two to six months) storage methods exist:—

(a) Above-ground circular slurry stores serviced by specialised submersible pumps.

(b) Compounds, normally with earth banks, the material being handled out in solid or semi-solid form.

Many problems have arisen with emptying of above-ground circular stores, virtually all of these attributable to mis-management of the system. Despite the availability of hydraulic and other methods of breaking up solid 'crusts' in store, exclusion of fibre, some degree of dilution of slurry (eg by parlour washings) and regular recirculation of store contents are the ingredients of successful management (Williamson 1978).

The main objective when emptying earth-banked slurry compounds is speed and ease of operation of the handling equipment, particularly where a contractor is involved, as this will minimise the annual costs incurred. The emptying equipment described below is basically designed for batch handling of solid material, thus any extraneous liquid within the compound can seriously affect workrate. It is therefore desirable to divert surface water away from the compound. Methods of extracting extraneous liquid from below the surface crust before emptying takes place include vacuum tankers, and purpose built "strainers" formed of welded steel mesh wrapped in plastics windbreak material, or railway sleepers with 12-25 mm gaps between them.

4 (iii) Equipment

Design and dimensions of compounds vary enormously. The basic concept normally involves earth banks and either an earth or concreted base, providing a 1.2-2.4 m (4·8 ft) storage depth. Contents can be emptied by either entering the compound and working within it, or from the banks using equipment with suitable outward and downward reach.

Basic types of equipment used are as follows:—

(a) Tractor mounted equipment

A 2-wheel drive tractor fitted with foreloader and bucket can achieve moderate work rates, servicing several spreaders, working from within a compound, provided there is a hard concrete base. The extra cost of this concrete can be offset by the fact that no specialised equipment is needed, and that if farm labour is available, the operation can be independent of a contractor.

A slew loader working from a static position is capable of working in an earth based compound, but unless this base is

Table 1 Mechanised clamp unloading

*(Number of asterisks * indicates quality of performance in this respect)*

Equipment	*Max operating height (range) m*	*Typical clamp unloading rate man min/tonne*	*Smoothness of silage face*	*Ability to handle long chop material*	*Typical extra capital cost*	*Comments*
Foreloader and fork	4.0-5.0	) 7.0) (4.0 using an) industrial	*	**	–	Equipment often already on the farm
Foreloader and fork with grab	4.0-5.0	) tractor) loader	**	***	£200-550	Grab attachment
Slew loader	3.0-4.0	4.5	**	***	£1900	Main equipment may be used for other duties on the farm
Foreloader with block cutter	4.0-5.0	)) 4.0-7.5)	****	****	£1000-1400)))	Blocks normally placed direct into
Rear-mounted block cutter	1.5-3.0 with high lift	))	****	****	£1200-1800))	feed passage or circular feeder
Semi-mounted loading feeder	2.0-3.0 with high lift	6.0-7.0[ϕ]	***	**	£1900-3000	Distributes feed to stock. Maize silage preferred.
Cutter loader	3.0-5.0	3.0-6.0	****	**	£4000 approx.	Specification and price depends on type chosen.

[ϕ] *Subjective estimate.*

particularly dry and compact, a concrete 'strip' is desirable to ensure access for spreaders.

(b) Tracklaying loaders/industrial 4-WD loaders

This type of equipment is commonly used by contractors for working within earth based compounds, and work rates of 60-80 m^3/hour are attainable provided that 3-4 spreaders are available to service the machine. The comments above regarding suitable access for spreaders obviously apply.

(c) Tracklaying hydraulic digger loaders

A large machine of this type commonly has a maximum horizontal reach of 9 m reducing to approximately 7.5 m when working midway between ground level and maximum digging depth. It can therefore be effectively used for emptying an earth based compound, working from the perimeter, provided that compound width is restricted to a maximum of 15 m and that both banks are accessible. The 360° slew facility allows spreaders to be positioned outside the compound perimeter for filling. Workrates are as high as 120 m^3/hour which can require 5-6 x 4.2 m^3 spreaders to service the machine.

Such equipment can also be used for working within earth-banked compounds not suitable for the above emptying method.

(d) Draglines

Maximum operating radius for these machines varies from 12 m–21 m and they can be used for emptying relatively large compounds by working from the banks. High work rates are attainable, but accurate positioning of the bucket when discharging slurry to the spreader is difficult.

4 (iv) Long term developments

The two basic methods of "long term" slurry storage are well established. The relatively expensive circular above ground store with pump emptying seems likely to gain in popularity, despite its relatively high capital costs, as it offers:—

(a) Flexibility of emptying date and therefore potentially better utilisation of plant nutrients, and

(b) better likelihood of acceptance if pollution control legislation is made more stringent in the future. Many dairy units however, have a potential major problem in the form of large volumes of "dirty water" yard run-off; in the majority of cases insufficient thought is given to the method of disposing of this liquid.

In the future, mechanical separation of slurry into solid and liquid fractions, predictable in their handling properties, may find a place on larger dairy units which are unable to find a conventional solution to their effluent handling problems. Adoption of the technique will depend largely upon the successful development of a simple, cheap and foolproof low volume irrigation system with minimum labour demands for moving pipework and sprinklers.

5 Conclusions

A declining agricultural labour force, less inclined to carry out manual handling tasks, necessitates the adoption of efficient handling equipment. Integrated systems to suit the varied tasks, often specific to individual farms, are needed.

In the recent past, the tractor with foreloader has been the general "maid-of-all-work" on the majority of farms, and this situation is likely to continue.

Larger holdings and agricultural contractors are likely to require more specialised equipment. The current vogue for rough terrain fork lift trucks (initially developed for the building industry) provides one possible answer, although this type of machine lacks the versatility of a tractor and can be regarded as a compromise answer in many livestock farming situations. The future may well bring specialised 4-wheel drive handling units, designed for the general needs of larger livestock farmers, and hopefully combining some of the advantages of all types of machine currently available.

References

ADAS Farm Mechanisation Study No 23.
Mechanised Feeding from Horizontal Silos, 1972.

ADAS Farm Mechanisation Study No 30.
Mechanised Feeding of Silage with other Feeds, 1977.

Shattock W S, Catt W R. Silage Systems – Practical mechanisation aspects. *Journal and Proceedings of Institution of Agricultural Engineers,* 1971 26(2) pp 62-68.

Williamson D A. Paper presented at Power Farming Conference, February 1978.

Providing the equipment 1

J K Avis

Summary

THE handling of bales on the farm is considered from the viewpoint of a manufacturer of handling systems. Inbuilt manufacturing flexibility, coupled to a constant awareness of ever changing requirements of agriculture, is essential.

With a topic as all embracing as farm materials handling it is convenient to illustrate the manufacturers' view-point by examining one specific activity to which first-hand experience can be related. Bale handling is a particularly suitable example. This subject is as topical as any farm handling problem and one, after all, which has presented a constant challenge to agricultural engineers in general and to my own company in particular for the past 20 years.

Due to the enormous permutations of farm situations, this topic is probably one of the most difficult to analyse briefly.

Until quite recently it had presented, and perhaps still does, one of the few remaining and certainly the most acute, handling problems to be overcome, compounded greatly in recent years by a steadily declining farm labour force. In the short time available it is only feasible to briefly assess the total problem of bale handling and outline the considerations which my company applies to market research, planning, engineering and production in an effort to provide workable and saleable solutions in the form of equipment.

First and foremost it is necessary to establish the overall objective and whilst this may seem academic it is nonetheless a crucial exercise in order to avoid the pitfall of producing equipment on an intuitive basis, and then attempting to justify a market following a commitment to manufacture.

As far as bale handling is concerned our own objective has been a fairly complete one, that is to say, an attempt to provide a wide range of systems which will be applicable to a very large percentage of the total sales opportunity.

Examination of the total market in statistical terms is a very necessary first step irrespective of the particular part of the market which is the ultimate sales target. Considering straw alone, and assuming that the entire production is baled, something in the region of 6 m tonnes of bales would need to be handled annually. The prime areas of straw production can be defined and furthermore it is possible to obtain a reasonable breakdown of the production source in terms of farm sizes. It is also known that there are currently some 90 000 balers in use on farms in the United Kingdom.

It would seem, therefore, that as a total opportunity the market is very attractive even accounting for the fact that probably only half of the volume of straw produced is eventually baled. From statistics such as these it is possible to start the process of compiling a "customer profile", which helps to establish in broad terms the particular sales target and the size of the market in both unit and value terms. Obviously other factors influencing the selection of a system have to be taken into account which are far less tangible from a statistical point of view.

The more important of these are:—

- Manpower available
- livestock type and numbers
- buildings and their location
- the proximity of industrial processing plants for straw
- social considerations
- capital availability.

By combining these factors with the information previously outlined the overall objective becomes more clearly defined. However, it is patently obvious that whatever the apparent merits of any one system it is unlikely to claim more than a limited proportion of what is estimated to be a much larger total market.

J K Avis NDA Tech(CEI) AIAgrE, Farmhand UK Ltd.

Paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The National Agricultural Centre, Kenilworth, Warwicks, on 9 May 1978.

Timeliness imposed by seasonal weather, and more recently, by the pressures of subsequent autumn cultivations is probably the one factor which most influences the application of a system in the farm situation. Table 1 highlights this. Clearly acreage, available man power and tonnage vary considerably according to farm size, the time available for baling and bale handling however remains constant.

With this background information in mind, the specific requirements of known customers' profiles can be gauged. At this point it is pertinent to refer to the same farm situations and establish the more specific demands on equipment in terms of its design and performance. The four most significant features are:—

- output
- simplicity
- labour requirement
- capital cost.

The table illustrates the relative change in priority according to farm size.

So far most considerations affecting the production and design of equipment have been imposed on the manufacturer by the operating requirements determined in turn by actual working conditions. Other factors which tend to be determined by the manufacturer, and are perhaps more crucial to the supplier than the user are nonetheless very important. These are principally:—

- durability
- versatility
- component interchangeability.

Table 1

Suggested systems	*Tons to move*	*Hours available*	*Men available*	*Capital cost*	*Cost per ton*	*Feature priority*
Simple flat 8 collector – 1 Fork	250	200	1	£850	£5.20	1. Labour requirement 2. Capital cost 3. Simplicity 4. Output
Flat 8 accum Flat 8 fork 56 bale carrier	800	200	2/3	£2200	£4.20	1. Capital cost 2. Simplicity 3. Output 4. Labour requirement
Large bale + carrier	1100	200	2	£6500	£3.17	1. Capital cost 2. Output 3. Labour requirement 4. Simplicity
Freeman system	2400	200	2	£40000 +	£4.12	1. Output 2. Labour requirement 3. Capital cost 4. Simplicity

Engineering time, evaluation, pre-production and eventually full-scale production can span periods of up to five years and the costs involved in each operation all have to be justified on the basis of projected sales. Frequently a similar period may be required for sales to accumulate to the break-even point. The case for getting the equipment right for the right market in the first place is, therefore, paramount.

Bale handling costs have been referred to briefly. These may seem more important to the ultimate purchaser than the manufacturer, nevertheless accurate cost data is relevant to long term developments. Detailed costs have recently been published which are a valuable aid to the selection of a system from the 30 or more currently available.

Table 2 compares 12 systems on the basis of seasonal output and indicates the effect of constraints imposed by 'spot' work rate and available time. It is particularly interesting to note that those systems which permit a high degree of mechanisation do not necessarily incur a high cost per tonne handled, given full utilisation.

Finally it is pertinent briefly to consider possible future trends in bale handling. It is predicted that these are likely to be influenced as much by the effects of known cost information of currently produced systems as by any other single factor.

The prime requirement will be for systems which allow a greater quantity of material to be handled in less time with fewer people. Table 2 also indicates the particular need to reduce the labour required as costs increase.

A trend towards high density packages will probably form the basis for improved efficiency and certainly this is likely to be the case in terms of big bales. However, the developing industrial requirement for straw is likely to point to a far more general trend in this direction particularly as the increasing need to convey straw by road over considerable distances calls for greater load factors in an effort to reduce overall handling costs.

However, this argument does not apply to 'on farm' handling requirements without qualification. Both the conventional and big bales currently available offer package sizes and weights which are ideally suited to handling on the farm during the winter months. A requirement for two quite separate types of baling system can therefore be predicted; one which is likely to be operated by contractors for industrial use and the other of a more conventional nature for domestic farm operations.

Manufacturers must accept that within any market, trends change, sometimes quite rapidly, and no more so than has been the case in recent years in the sector of bale handling equipment. Whilst every supplier hopes to achieve the largest possible production run from any product, this in itself should never cloud the issue to the point where progression is overlooked in the interests of short term profit. Inbuilt flexibility, coupled to the constant awareness of the changes that are continually demanded by agriculture, are absolute essentials not only to commercial success but also to the satisfaction of the farming community which our industry serves and perpetually relies on.

Table 2 Summary of system costs including bale and handling.

System	*Tonnes[1] handled*	*Cost £/tonne handled*			
		Cost of tractor and man £/h 3.00	4.00	5.00	6.20
Flat ten	1088	4.19	4.64	5.07	5.59
Double flat eight	608	3.09	3.55	3.98	4.42
Freeman System	2438	4.12	4.25	4.38	4.16
Accumulator fork	263	5.27	6.28	7.30	8.52
Howard (carrying 1 bale/run)	1090	3.62	4.21	4.86	5.48
Large bale mover (Farmhand x 5) (to field rows only)	968	3.17	3.46	3.73	4.07
Flat eight	800	4.21	5.03	5.84	6.81
Cube-8 (Lely) (carrying 48 bales/run)	800	3.28	3.75	4.23	4.81
Strapped package (McConnel)	840	4.43	4.92	5.40	6.33
Automatic trailer (SNH)	1500	4.28	4.55	4.82	5.14
Large round baler (5 ft) to stacks (carrying 1 bale/run)	968	3.63	4.26	4.88	5.62
Large round baler (4 ft) (carrying 1 bale/run)	713	4.76	5.60	6.44	7.45

[1] Assumes annual use 200 hr

Providing the equipment 2

H J Carnall

Summary

THE fork-lift truck has a well established place on the farm. The options available to the customer and the characteristics of types are related to manufacturing criteria.

Brief history

To those in the lift truck industry, the terms mechanical or materials handling are synonymous with lift trucks, and you will no doubt notice that the term "lift truck" is used as opposed to fork lift truck.

The lift truck industry is relatively young, having its roots in about the middle war years when a small number of American industrial trucks was brought over for military handling and storage use on especially prepared sites. The application of lift trucks to agriculture is more recent, their use being more common in the last five or six years. The first version of what are now generally known as rough terrain trucks was introduced as a forestry truck in 1966 by Bonser. This truck had a lift capacity of 7500 lb (3401 kg) with axle weights of:— front 3410 kg, rear 3853 kg, and a wheel base of 203.8 cm. One of the great problems of those formative times was to find a tyre capable of carrying the load but with sufficient traction to drag the unladen vehicle, with its heavy rear end, through rather than over difficult tracks. The solution then was to use "earth mover" type tyres on the drive axle and 'combine' flotation types on the rear. This combination proved successful as the model continues in production and many of the early machines are still at work.

There is an ever increasing use of what are termed "industrial lift trucks" in the farming and food processing industries. For an industry quite as young, one could be forgiven for imagining that the choice in providing the equipment was simply a matter of listening to what the farmer required and fulfilling his wishes, but unfortunately this is not the case.

The choices for the user

Apart from the obvious one, of which manufacturer to choose, the basic options open are usually centred around the type, capacity and the associated equipment with which the vehicle will finally be fitted. Other features must also be considered as most manufacturers offer a range of transmission forms:— mechanical, hydrokinetic and hydrostatic, a wide selection of mast types for special duties and a whole range of special attachments and ancillary equipment.

There are two main types:—

(i) The "industrial" vehicle which is normally very compact and highly manoeuvrable, has small wheels and a quite remarkable carrying capacity for its size. It is used where floor area is at a premium, with reasonably smooth surfaces as traction is often limited.

(ii) The 'rough terrain' truck may have four wheel drive, invariably has large tractor type tyres on the drive axle, which is usually the load axle, and has carrying capacities normally up to 2500 kg. As the name implies this type is capable of traversing completely unmade sites, fields etc., and can often cope with extremely steep gradients with a good deal of built-in safety.

To assist the customer in selecting from this range of combinations, the manufacturer provides specialist advice normally given by applications engineers, whose job it is to sort out the problem areas and recommend a complete system.

Manufacturers problems

These generally fall into two broad categories, those of a technical nature and those which are commercially orientated. Technical problems can be further sub-divided into two broad classifications as follows:—

(i) Externally determined

These are due to legal or moral constraints beyond the direct influence of the farmer. For example, the Health and Safety at Work Act is creating problems for all manufacturers in areas where two or three years ago, user, manufacturer and inspector accepted that some risks were inevitable. The regulations of the Common Market countries also have a pronounced effect upon the design and particularly small elements of it such as tyres, lights, and hydraulics. The problem of noise attracts recurring comment and discussion.

Strangely there is very little legislation in our industry and most of the obligations we have are from a strictly moral point of view. The recommendations by the British Industrial Truck Association are probably the best example, and of these the most important is, without doubt, stability, a feature that no designer would attempt to compromise to even the smallest degree. The same reasoning applies for the factor of safety in the strength of the forks, in the strength of the lift chains and even the diameter of the pulleys over which the chains pass, and there are many more.

→page 80

H J Carnall CEng MIMechE, Bonser Engineering Ltd.

Paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The National Agricultural Centre, Kenilworth, Warwicks, on 9 May 1978.

(ii) Internally determined

After a market analysis of the requirements and having set down further features for the design, based on what the farming community needs and what the company is capable of providing, the key questions can be established which will enable the engineer to start a design, as follows:—

(a) Should the vehicle be multi purpose or single purpose? Most would agree that the multi purpose machine never does all tasks quite so well as the specialist counterpart. However, as indicated at the beginning of this paper, modern lift trucks for farm use are very like agricultural tractors, in that their effectiveness depends very much upon the implements attached to them. Effective attachments thus permit a basically single purpose vehicle to fulfill a multi-purpose role.

(b) What power output is required to do this job and what form of transmission should it have? What type of chassis support system is required to tie the whole together? Indeed what can the company best provide to fulfil this requirement?

(c) What labour will be required from the farmers point of view to utilise the lift truck with its attachments in the many special handling tasks to be found on a modern farm? Does this imply any constraints on capital cost?

(d) Are there any other unusual areas that should be investigated, services to be provided or conditions to be fulfilled?

Multi purpose v single purpose

In the past most rough terrain trucks have been based on a tractor skid unit, which automatically offered the farmer well proven, reliable, easy to obtain components, with matched transmission and engines, and usually has been well capable of carrying the unit loads required on farms. Both an industrial and a rough terrain truck may be based on a skid unit but with marked differences in overall dimensions.

Although this technique offers possibly the best value for money, it does have constraints and if the tractor manufacturer makes changes, the fork truck manufacturer must follow suit which may be costly and quite often contrary to the need of the end user. It could be argued, therefore, that a carefully chosen power unit, with matching transmission and chassis, offers the best compromise in terms of value for money and overall performance.

Power unit

Having selected a skid unit, the power is generally pre-determined. However in a recent design my company selected a non-skidded unit which allows the use of a small engine running quite slowly to give the best performance in terms of noise and fuel consumption. When matched to a multi speed gearbox a wide range of tasks can still be accomplished, albeit some of them more slowly than by its highly powered brothers. Most power is required by the hydraulic services and the lifting circuit in particular; 26 kW is quite common so that there is little reserve in the normal type of power unit for additional work. This however is justified as the lifting and transporting functions should not be concurrent. The normally accepted power payload ratio seems to be in the range 7 to 11 kW per 750 kg lift capacity range. This is usually coupled with the ability to travel at up to 25 km/h and to climb gradients of 20% or more.

Labour requirement

To minimise the labour involvement there is an amazing number of attachments designed for specific duties, often made by associate companies. Great care should be taken when fitting these attachments and the advice of the truck manufacturer and the attachment supplier should be sought in order to guarantee safety. These devices may necessarily be heavy in themselves and, when carried with a good pay load well in front of the supporting axle, vehicle stability may be impaired. To help alleviate these problems, each type of truck is very thoroughly stability tested. Most possible conditions of use have been considered and a safe solution found. Some large companies and government bodies, however, often insist on one or two extra tests, one of the most popular being a test where a dynamic load is considered to be the safe working load; that is one which can be tilted forward to the trucks capability whilst on the tilted platform. It follows that this would cause a considerable derating of the vehicles normal payload, as indeed would any large object placed between the existing mast and the centre of gravity of the normal load.

Special facilities

The need to provide special facilities is difficult for the manufacturer to determine. Examples can be cited such as requests to fit hydraulic quick hitches for trailers, power driven generators and power take offs of all kinds. Most could be proved to be extremely useful and a place for them adequately justified, but is not necessarily the area of speciality that the truck manufacturer should be (or wants to be) involved in. My company has a patent application for a hydraulic ring main on a lift truck, so that the hydraulic services are already provided for such things as a power driven generator, silent road drill, circular saws, hydraulic spreaders etc. The problem is resolved simply by weighing the cost against the likely return.

Another important point is the ability to service the vehicle easily, ideally with plentiful, reasonably priced spare parts with the minimum of labour and equipment and without having to remove half the vehicle for this to be achieved. The user ought to be able to change a clutch, even the crown wheel and pinion or gearbox bearings, without having to split the vehicle. Equally, it should be possible to service the brakes and attend to wheel bearings without having to remove an axle and with it the mast which it often supports. The ability to service the hydraulic cylinders without removing them from their anchorages is also helpful. Such features have either to be developed and/or considered for a long period until a solution evolves. Feed back from dealers is especially beneficial in this respect together with guidance on the special requirements of particular geographic locations and so on, all of which are carefully analysed and where practicable incorporated into existing or future machines.

Other technical problems

Other areas of concern are, for example, the tyres. Invariably the design requirements are high carrying capacity, low inflation pressure, good flotation, and even better traction. Often it is difficult to find the tyre to fulfil all these conditions at the same time. Even if it were possible to make such a tyre, the total industrial demand would be limited, resulting in a high price. Once again, a compromise is inevitable.

On our products the wheels are always mounted on an accurately machined spigot with flat nuts forming a friction grip against the nave plate rather than having coned outs seating into coned or semi circular housings. This action is justified by the thought that the large diameter metal spigot is quite capable of carrying the vertical loads imposed upon it and since the studs could be a better fit in the hole, they could be aided by the friction grip of the nuts to transmit the torques involved. It would, however, be impossible in commercial circumstances to achieve absolute precise pitching that would guarantee coned nuts and the studs particularly, carrying an equal share of the driving torque.

ISO have recently a standard to cover this form of mounting.

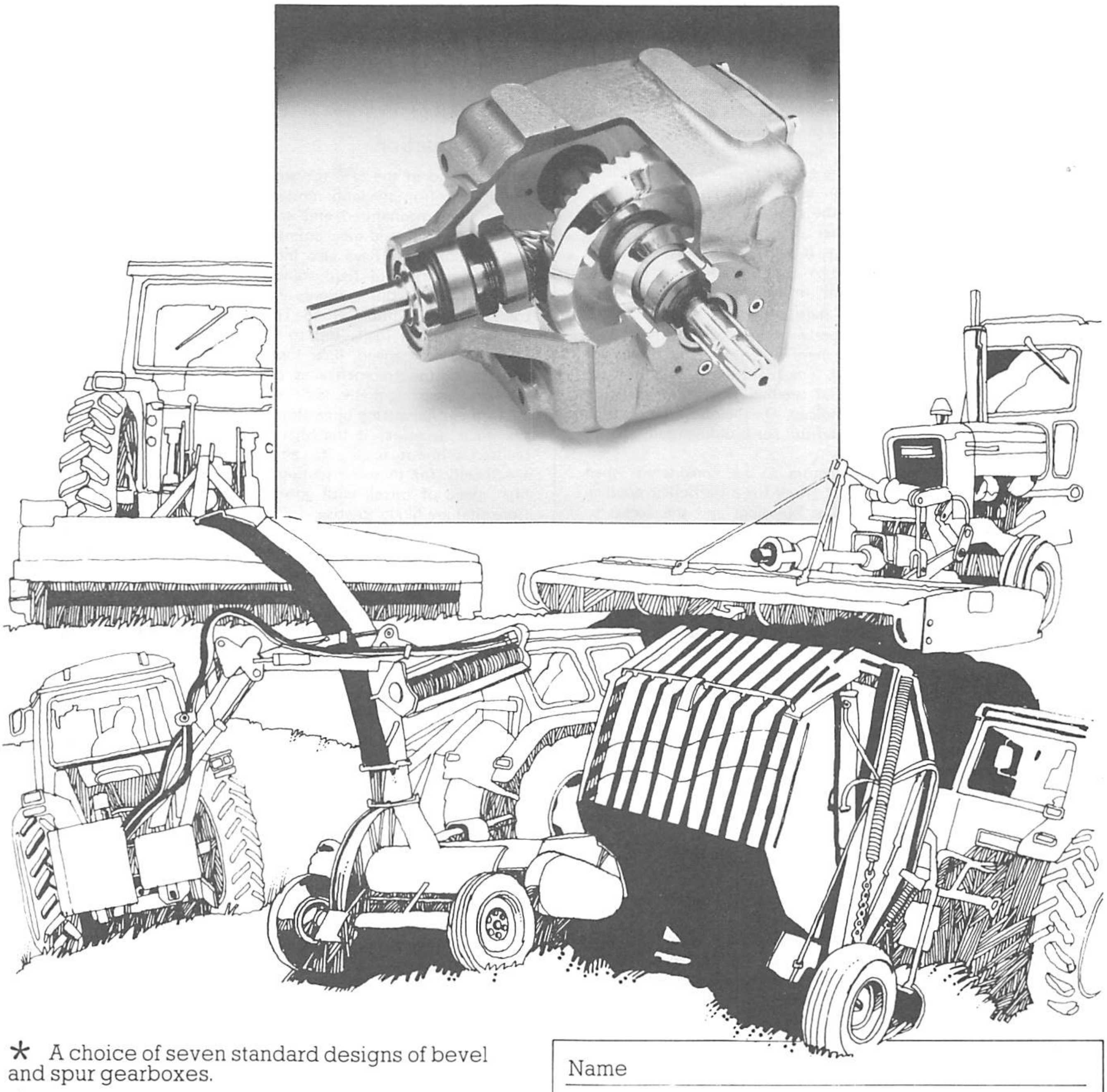
To metricate or not to metricate, that is a difficult question. Tractor manufacturers, engine manufacturers and a good many other suppliers are not yet fully metricated, so that hybridised vehicles may be necessary for some time yet. Nevertheless we are a metric organisation and doing our best to change as quickly as possible.

Commercial considerations

1 Manufacturers

Having decided that a new vehicle is required to fulfil a need, there must be sufficient potential to justify the financial involvement, the extent of which is not readily apparent. To produce a prototype is probably the smallest single cost item of any new product development, and experience shows that this varies between three and five times the final selling cost of the vehicle, depending upon the degree of novelty and good fortune during development and testing. The weather plays an important part in the length of the overall test programme. There are often changes to be made, not only because of design considerations, but due to changes in legislation. All erode time and increase cost. When all the costs are accounted for, including tooling, publicity of a technical nature, space to assemble and so on the bill now cannot be less than £100 000 and that sounds so round as to be almost made

→ *page 82*



up, but is none-the-less true. Plainly the marketing specialists must be very persuasive, accurate, competent and perhaps above all sympathetic. If the new machine is not considerably different from its predecessors, it may well be possible to built it as a mix along the same assembly lines and thus keep some of the costs to a minimum. However, this is usually treated as a bonus.

2 Customers point of view

The question 'how much should I pay for the lift truck of my choice' might well be answered along the following lines, 'buy the most effective for the task to be performed, and the best that you can afford'. If it costs £12 000 today, its second hand value is likely still be to be £12 000 in three years time. With good budgetry control, its value will surely have been written down in any case, and with good utilisation more than its value should have been saved, particularly as it can be shown that some 40% of farm task are in moving things from one place to another. Many factors should be taken into account:— the economy of running, the cost of spare parts, the comfort of the operator (including visibility, quietness, ergonomics generally), the cost of replacing tyres and perhaps even its appeal to another user as second hand value.

It is worth bearing in mind that it is considered by some that independent of the size of the farm and the products handled, todays lift truck is probably better utilised than many tractors. Indeed some estimates suggest that these vehicles are used for 70% of the available time. When properly equipped and used in a considered group of applications, there are not many duties for which the vehicles cannot be used. The main exceptions perhaps are cultivation, soil preparation and seeding where the vehicle's weight distribution is a definite handicap. On the other hand a high working platform can be put to good use for building maintenance and construction.

Among the most important factors to be considered when investigating the suitability of a lift truck for a particular application are the size of the openings in buildings and the access to them. Most truck manufacturers now publish a diagram indicating the minimum turning circles that a vehicle with a standard load can negotiate and usually referred to as 90° stacking, 45° stacking, and a 180° turn, which incidently is not just twice the outer turning radius. In other words before taking on a truck, the user must be absolutely sure that all the apertures through which it must pass in height, width and length are suitable, and if the truck chosen happens to be of the industrial variety, gradients, surface of the gradient and the ability of the truck to climb these must be checked.

The following cycle times are considered typical, assuming the lorry to be loaded is within a reasonable distance, and depending upon the height of the sides of the lorry.

Beet requires about 1.00 minute per ton to load
Grain requires about 1.00 minute per ton to load
Muck requires about 1.25 minutes per ton to load.

Each time a truck is used in this type of application, a tractor is released for its more normal tasks, such as towing and cultivation; thus the utilisation of the tractor is also improved with a beneficial effect on the costs for machinery as a whole.

In order that both sides can obtain maximum benefit from it, our company has an "open house" policy for visitors where we welcome, as guests, anyone from customer to competitor, ideally in groups of not more than ten and with similar affiliations and at mutual agreeable times. Perhaps by this means we can appeal to the not so well-to-do farmer and produce a specification for the ideal farming lift truck of the future.

Materials handling

A G Dumont

Summary

A MIXED integer/linear programming model has been developed to study the problems of allocation of men and machinery on an arable farm over the year.

The model uses men and equipment as integer resources and land use and work done in each period of the year as continuous variables.

1 Introduction

With a trend in the UK towards bigger farms and a movement of labour away from the land, modern farming operations are becoming increasingly mechanised and complex. In order to maximise the benefits of increased mechanisation and larger field sizes, harvesters and traction units have also increased in size and work rate. The standard method of field transport, however, for on-farm movement of seed, fertiliser, sprays and harvested crops is still mainly the tractor/trailer combination. This method of transport is well suited for small loads (up to 5 t) and short distances. Because of its low road speed, light load and poor traction under adverse conditions, the tractor/trailer combination may not be suited to modern harvesting methods on larger farms.

In most harvesting operations on arable farms, a good transport system is necessary if the high work rates of harvesters are to be realised without having to employ a large number of workers specifically for these harvesting operations. Good transport means high speed of travel, with good size loads under most field conditions that are likely to arise.

There are many options for farm transport, for example, bigger trailers, specialised trailers or specialised multi-purpose transport vehicles. The economic benefits of these, or other, changes to transport on the farm depend on many things such as opportunity cost, performance, machine capability and job requirements. This paper describes an application of a linear programming model to study the economics of different transport systems on arable farms.

2 A mixed integer/linear programming model

A linear programming model is a set of linear equations. The equation variables represent the possible activities to be carried out in the systems being modelled. With one exception, all the equations represent constraints on the system, for example, the number of men available. The one exception is an equation, called the objective function, which represents a chosen output from the system. The linear programme maximises the objective function while satisfying all the constraints applied. These constraints may be limits on the resources available or they may represent physical, logical or economic limits on the system being modelled.

In a mixed integer/linear programme (I/LP) some of the activities must take whole number values, for example, the number of men employed. Other activities may have any positive value, such as: area of a crop grown or hours worked in a period.

To study resource allocation on the farm, an I/LP model was developed. The activities include:—

(a) Resources: Men, machines, land and time, which are either limited or cost money.

(b) Operations: Both transport and cultivation operations to be done by the resources available, in correct sequence and at permitted times.

(c) Outputs: Crops, which give a gross margin depending on how much is grown and when.

The model represents an arable farm over a whole year. The

A G Dumont BSc MSc(OR), Systems Department, National Institute of Agricultural Engineering, Silsoe, Bedford.

Paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The National Agricultural Centre, Kenilworth, Warwicks, on 9 May 1978.

on the farm - The systems approach

year is divided into half-month periods and in each period there is a limited time, with the resources available, to carry out the required operations.

Table 1 Integer resources available in the farm model of transport systems.

Resource type	Code letters	Annual cost £	Hourly cost Normal £	Hourly cost O/time £
Man	MA	2000	0.0	1.5
Medium tractor – 50 kW	T1	1380	0.8	0.8
Large tractor – 100 kW	T2	1750	1.0	1.0
4-wheel, flat bed trailer (3 t load)	FB	110	0.2	0.2
2-wheel, tipping trailer (5 t load)	TT	195	0.3	0.3
Sprayer (1500 – trailed)	SP	360	0.3	0.3
Special transport (5 t load)	TR	9100	1.0	1.0

2.1 Resources

Table 1 gives a list of the integer resources available on the farm. Where other equipment is required, this can be included. These resources are integer activities, that is the model must choose whole numbers of each one.

Table 1 gives the annual and hourly cost of these resources. The annual cost of a man is his wages, while the annual cost of a piece of equipment is found by discounting its capital cost over its useful life[1]. The hourly machine costs are given by Nix[2] or calculated from various references in the literature.

Non-integer resources available in the model are land, which is set to a level depending on the size of farm being studied, and time. Table 2 shows the hours available for field work in each half-month period of the year.

Table 2 Man hours available for field work (Nix[2])

Period Month	Half	Normal hours	Overtime hours
1	1	37	14
	2	37	14
2	1	33	16
	2	34	17
3	1	44	34
	2	45	35
4	1	45	43
	2	45	43
5	1	53	55
	2	53	55
6	1	56	56
	2	56	56
7	1	59	57
	2	59	56
8	1	56	52
	2	56	52
9	1	53	41
	2	53	41
10	1	50	32
	2	49	31
11	1	36	13
	2	36	13
12	1	34	13
	2	33	12

2.2 Operations

In order to produce crops, operations must be done on the areas of each crop, in the permitted periods of the year, in the required order, using the resources available. The time to complete each operation depends on the team (men and equipment) used for the operation. The set of operations required, the teams used and the calculated time for each operation, for the 200-400 ha farm modelled are shown in table 3. The permitted periods when each operation can be carried out are shown in fig 1.

key
P = plough
C = cultivate
D = drill
F = fertiliser
G = combine
H = harvest
S = spray

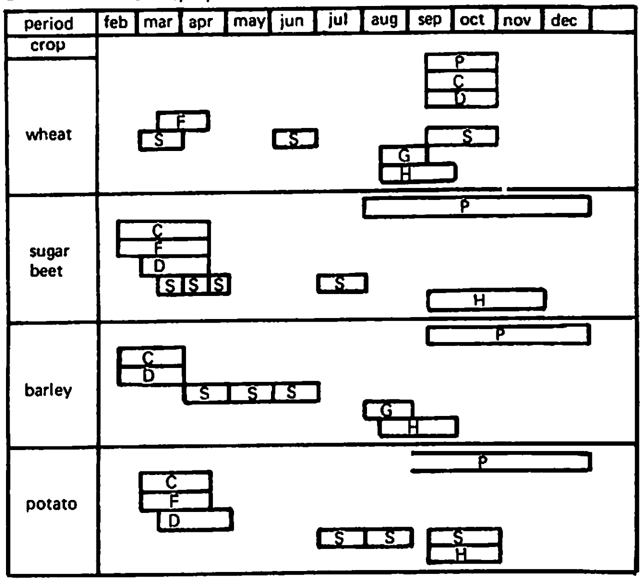


Fig 1 Permitted times for each operation on each crop over a year.

Although some operations may be done over several periods, there may be a best time for the operation and if it is done earlier or later a yield penalty results. The timeliness costs used in this study are based on yields of crops sown or harvested at varying times in Agricultural Development and Advisory Service trials given in table 4.

2.3 Objective function

The gross margins for the three crops which are included in the model are:[2]

Winter wheat	–	£300/ha
Spring barley	–	£250/ha
Sugar beet	–	£600/ha.

The objective function of the farm I/LP model included these margins less the cost of men and machinery less various penalty costs for bad timing of the operations.

The model maximises the gross margin of the farm over a year by optimising: Expenditure on men and equipment, overtime worked and timeliness costs. Where possible, depending on rotation constraints or crop area limits, the model may also change the crop mix to make the best use of the resources available.

The model compares farms, using different transport systems, under optimal conditions in each case.

→page 84

Table 3 Work rates and team sizes for each operation on each crop (tractor/trailer only), 200-400 ha farm, 1 km travel distance, 75% over fields.

Operation	Crop	Number of each resource type						Rate of work
		MA	TG*	T2	FB	TT	SP	h/ha
Plough	Wheat	1		1				1.0
	Barley	1		1				1.0
	Sugar beet	1		1				1.0
	Potatoes	1		1				1.0
Cultivate	Wheat	1	1					2.0
	Barley	1	1					2.0
	Sugar beet	1	1					2.0
	Potatoes	1	1					2.0
Fertiliser spread	Wheat	1	1		1			0.2
	Barley	1	1		1			–(1)
	Sugar beet	1	1		1			1.0
	Potatoes	1	1		1			1.0
Drill	Wheat	1	1		1			0.5
	Barley	1	1		1			0.5
	Sugar beet	1	1					1.0
	Potatoes	1	1		1			4.4
Spray	Wheat	1	1				1	0.2
	Barley	1	1				1	0.2
	Sugar beet	1	1				1	0.2
	Potatoes	1	1				1	0.2
Harvest	Wheat	4	2			2		0.8
	Barley	4	2			2		0.8
	Sugar beet	4	2	1		2		6.7
	Potatoes	4	2	1		2		10.0
Harvest straw	Wheat	2	2		1			2.3
	Barley	2	2		1			2.3

**This resource implies a general tractor, ie T1 or T2 may be used.*

(1) Fertiliser applied when drilling.

Table 4 Timeliness penalty costs for operations at different periods of the year.

Crop	Winter Wheat									
Operation	Drilling					Harvest				
Period	09-1*	09-2	10-1	10-2	11-1	–	08-1	08-2	09-1	09-2
Adjustment to gross margin £/ha	–132	-49	-8	0	-23	–	0	-4	-11	-30
Crop	Spring Barley									
Operation	Drilling					Harvest				
Period	02-2	03-1	03-2	04-1	–	–	08-1	08-2	09-2	–
Adjustment to gross margin £/ha	0	-16	-32	-51	–	–	0	-3	-10	–
Crop	Sugar Beet									
Operation	Drilling					Harvest				
Period	02-2	03-1	03-2	04-1	04-2	09-1	09-2	10-1	10-2	11-1
Adjustment to gross margin £/ha	-187	-75	0	-52	-134	-188	-98	-45	-15	0
Crop	Potatoes									
Operation	Drilling					Harvest				
Period	-	03-1	03-2	04-1	04-2	09-1	09-2	10-1	10-2	11-1
Adjustment to gross marin £/ha	-	-495	-61	0	-165	-99	-33	0	0	-33

**09 refers to month, ie September*

-1 (2) refers to first (or second) half of month.

3 Comparison of a special transport vehicle and tractor/trailer.

For this study, the model was used to compare an arable farm using a conventional tractor/trailer system with a proposed special transport vehicle estimated to cost £25 000 to purchase or £9100/year to own[1]. It is equipped with three interchangeable bodies:

(a) Load carrying at harvest, with a capacity of 5 t, travelling up to 20 km/h over fields and 30 km/h on roads.
This compared with a tractor and trailer with a capacity of up to 5 t, travelling at up to 10 km/h over fields and 20 km/h on roads.

(b) Spraying with a tank capacity of 5000 litres, a boom width of 15 m, travelling at 15 km/h.
This compared with a tractor and trailer sprayer, with a 1500 litre tank, 12 m boom, travelling at 8 km/h.

(c) Fertiliser spreading, with a load of up to 5 t, a spreading width of 10 m, at a speed of 10 km/h.
This is compared with a tractor and spinner, with a 1 tonne capacity loading from bags in the field, spreading over 10 m, at 8 km/h.

3.1 Transport conditions

Arable farms of 200, 300 and 400 ha with three crops: winter wheat, spring barley and sugar beet were considered:

Three transport conditions for each farm area were used:

(a) An average travel distance of 1 km, 75% over fields, 25% over roads, for all operations.

(b) An average travel distance of 2 km, all over fields, for all operations.
This was to represent poorly laid out farms with poor roads.

(c) As for (a), but the work rate for sugar beet harvesting using tractors and trailers was reduced by 50%. At the same time, the ploughing rate for both tractor/trailer and special transport farms, was reduced by 50% to reduce the time for operations at this critical time of the year. This was to show the effect of the special transport vehicle in an unfavourable season.

3.1 (a) Average travel distance — 1 km, 75% over fields

The work rates using the special transport vehicle are given in table 5, for a 1 km travel distance, 75% over fields.

Table 6 shows the resources required by the model for the 200, 300 and 400 ha farm under optimal conditions for the farms with tractor/trailer or special transport vehicle.

These show that for each farm size, the gross margin per hectare for the farm with a special transport vehicle is significantly lower than that with tractors and trailers. For the 200 ha farm,

Table 5 Work rates and team sizes for operations using the specialist transport vehicle 200-400 ha farm, 1 km travel distance, 75% over fields

Operation	Crop	Number of each resource							Rate of work
		MA	TG*	T2	FB	TT	SP	TR	h/ha
Fertiliser	Wheat	1						1	0.13
	Barley	1						1	0.21
	Potatoes	1						1	0.23
Spray	Wheat	1						1	0.10
	Barley	1						1	0.10
	Sugar beet	1						1	0.10
	Potatoes	1						1	0.10
Harvest	Wheat	3						1	0.80
	Barley	3						1	0.80
	Sugar beet	3		1				1	6.70
	Potatoes	4	1	1		1		1	10.00

**T1 OR T2 can be used.*

Table 6 Resources used in optimal solutions with (B) and without (A) the special transport vehicle 1 km travel, 75% over fields.

Farm size, ha		200		300		400	
Resources	Maximum	(A)	(B)	(A)	(B)	(A)	(B)
Men	10	8	6	8	9	10*	10*
Medium tractor	6	4	2	4	3	5	4
Large tractor	4	2	2	2	3	3	3
Flat bed trailer	3	2	2	3	3	3*	3*
Tipping trailer	4	4	2	4	2	4	2
Sprayer	1	1	0	1	1	1	1
Combine harvester	2	1	1	1	1	1	1
Beet harvester	3	2	2	2	2	2	2
Special transport	2	0	1	0	1	0	1
Gross margin £/ha year		224	207	234	219	226	219
Total difference in margin £/year			-3400		-4500		-2800

**Gross margin would be increased with more of this resource.*

Table 7 Work rates and team sizes for each operation on each crop for 200-400 ha farms, 3 km travel distances, all over fields

	Crop	*Method*	*Number of each resource type*							*Rate of work*
			MA	*TG**	*T2*	*FB*	*TT*	*SP*	*TR*	*h/ha*
Fertiliser	Wheat	1	1	1		1				0.22
		2	1						1	0.13
	Barley	1	1	1		1				1.00
		2	1						1	0.27
	Potatoes	1	1	1		1				1.20
		2	1						1	0.32
Spray	Wheat	1	1	1				1		0.25
		2	1						1	0.10
	Barley	1	1	1				1		0.25
		2	1						1	0.10
	Sugar beet	1	1	1				1		0.25
		2	1						1	0.10
	Potatoes	1	1	1				1		0.25
		2	1						1	0.10
Harvest	Wheat	1	4	1			1		1	0.80
		2	4						2	0.80
		3	5	3			3			0.80
	Barley	1	4	1			1		1	0.80
		2	4						2	0.80
		3	5	3			3			0.80
	Sugar beet	1	4	1	1		1		1	6.70
		2	4		1				2	6.70
		3	4	2	1		2			6.70
	Potatoes	1	4		1				2	10.00
		2	5	3	1		3			10.00

**Implies T1 or T2 may be used.*

one special transport vehicles saves: two men, two medium tractors, two tipping trailers and a sprayer. But the gross margin is still reduced by £3400/year. This means that the special vehicle would become competitive at an annual cost to the farmer of £5700/year or a capital cost of £15 600. For the 400 ha farm where the resources allowed have become limiting, the special vehicle saves only one medium tractor and two tipping trailers, and is still too expensive. In this case it becomes competitive at £6300/year, to a capital cost of £17 300.

3.1 (b) Average travel distance — 3 km, all over fields

The work times and teams for each operation using tractor/trailer or special transport vehicles are given in table 7, for a 3 km travel distance, all over fields.

The teams are the minimum needed to support the harvesting rates used. For example, in sugar beet harvesting, a trailed harvester with a 1.5 t capacity tank can work at a rate of 6.7 h/ha. For a travel distance of 3 km, over fields, this requires one of the following teams:—

(1) Four men, one medium tractor, one large tractor, one harvester, one tipping trailer, one special transport vehicle.

(2) Four men, one large tractor, one harvester, two special transport vehicles.

(3) Four men, two medium tractors, one large tractor, one harvester, two tipping trailers.

Table 8 shows the resources and gross margins using the two transport systems, on 200, 300 and 400 ha farms.

Table 8 Resources used in optimal solutions with (B) and without (A) the special transport vehicle 3 km travel, all over fields

Farm size, ha		*200*		*300*		*400*	
Resources	*Maximum*	*(A)*	*(B)*	*(A)*	*(B)*	*(A)*	*(B)*
Men	10	8	8	9	9	10*	10*
Medium tractor	6	3	2	4	3	6*	4
Large tractor	4	3	3	3	3	3	3
Flat bed trailer	3	2	2	3	3	3*	3*
Tipping trailer	4	4	3	4	3	4*	3
Sprayer	2	1	0	1	0	1	0
Combine harvester	2	1	1	1	1	1	1
Beet harvester	3	2	2	2	2	2	2
Special transport	2	0	1	0	1	0	1
Gross margin £/ha year		221	187	232	211	218	209
Total difference in margin £/year			-6800		-6300		-3600

**Gross margin would be increased with more of this resource.*

Once again the gross margin per hectare is lower for the special transport than for the tractor/trailer farms. For the 200 ha farm, the special transport can only replace: 1 medium tractor, 1 tipping trailer and a sprayer, and requires an extra beet harvester. The total loss in gross margin is £6800/year. The special transport vehicle would only become competitive at an annual cost of £2200, corresponding to a purchase price of £6000.

Even for the 400 ha farm, the special transport vehicle replaces only two medium tractors, one tipping trailer and a sprayer. It would be competitive at an annual cost of £5500, or a purchase price of £15 100.

These results rather favour the tractor/trailer because at a travel distance of 3 km, over fields, the most important operation, the sugar beet harvest, can still be done with 2 tractors and trailers which can only be replaced by a more expensive combination: 1 special vehicle plus 1 tractor and trailer, or 2 special vehicles. At a greater travel distance (unlikely in practice), the special vehicle may show more advantage.

3.1 (c) Reducing the work rate of the sugar beet harvest by 50% when using tractors and trailers, and reducing ploughing rate for both systems.

To show the possible benefits of a special transport vehicle increasing the harvesting rate for sugar beet, and with reduced time available, the harvesting rate for sugar beet using tractors and trailers was reduced by 50%. At the same time, the ploughing rate, which competes for men and large tractors at this time was also reduced by 50% for both tractor/trailer and special transport farms.

Table 9 shows the resources and gross margins using the two transport systems on a 200, 300 and 400 ha farm.

Table 9 Resources used in optimal solutions with (B) and without (A) the special transport vehicle 1 km travel, 75% over fields, sugar beet harvesting rate reduced by 50%.

Farm size, ha		*200*		*300*		*400*	
Resources	*Maximum*	*(A)*	*(B)*	*(A)*	*(B)*	*(A)*	*(B)*
Men	10	8	6	9	9	10*	10*
Medium tractor	6	3	2	4	2	6*	2
Large tractor	4	3	2	3	3	3*	4*
Flat bed trailer	3	2	2	3*	2	3*	3
Tipping trailer	4	4	2	4*	2	4	2
Sprayer	1	1	0	1	0	1	1
Combine harvester	2	1	1	1	1	1	1
Beet harvester	3	2	2	2	3	2	3
Special transport	2	0	1	0	2	0	2*
Gross margin £/ha year		186	192	195	202	195	205
Total difference in margin £/year			+1200		+2100		+4000

**Gross margin would be increased with more of this resource.*

In this example the special vehicle shows an increased gross margin for all farm sizes compared with the tractor/trailer farm. For 200 ha, one special transport vehicle replaces: two men, one medium tractor, one large tractor, two tipping trailers and one sprayer. The gross margin is increased by £1200/year. This makes the special vehicle competitive even at £10 300/year, or a purchase price of £28 300.

For the 400 ha farm the total gross margin is increased by £4000/year using two special transport vehicles, which would make one competitive at a cost of £11 100/year, corresponding to a purchase price of £30 500. The results for a 400 ha farm favour to some extent the special transport vehicle because of the resource limits imposed. These results do, however, highlight the obvious advantages of improving work rates at critical times and also the obvious penalty costs of limited resources for carrying out crucial operations.

4 Conclusions

The results indicate that under the set of conditions studied, saving on other resources at harvest time is not usually enough to justify the price of £25 000 for the special transport vehicle. In the example given, Tables 6 and 8, the vehicle would become competitive with tractors and trailers at a price of £17 300 in the best case, and £6000 in the worst.

If the special vehicle improves harvesting rate under critical conditions, then it does become competitive at £25 000 and indeed, under extreme conditions, could be worth £30 000 to a farmer (table 9). → *foot page 86*

Handling agricultural materials

Edited summary of discussion

P Wrixon (Herefordshire farmer and BBC TV presenter), opened the general discussion, and said:—

The future of materials handling is guaranteed by the positive disincentive for employing labour that exists today, giving rise to a polarisation towards family and institutional farms.

Some say there is no better incentive for better equipment than the boss having to do the job himself for a few days. The trend towards winter cereals requires timeliness and, hence, better handling.

Tax averaging (when we understand it) may lead to many farmers postponing spending on materials handling equipment indefinitely. Statistics quoted by the speakers show that 12% of farms handle 50% of the produce, much of which is handled several times; 70% of the total tonnage is handled on livestock farms and this is an area where there is little money left for investment. I want simple, affordable, easy to put on and take off equipment. Did Mr Avis take other factors into account when showing the effects of increase in the cost of labour?

Are those involved in complete feeding getting a good enough return? They have had a massive investment per cow in the last two years. What is likely to happen to fork lift trucks sales if potato prices stay at this year's level rather than the last two?

J K Avis commented that the costs quoted were to highlight the effects of altering labour expenses, not depreciation of machines.

W R Butterworth (Writtle Agricultural College) asked where the tractor fitted into the principles of materials handling.

J B Holt replied that the tractor can travel at high speed, combining two operations of high draft and high speed operations. However, he was in doubt as to the suitability of this marriage.

R H F Jeffes (Farmer and inventor) questioned the advisibility of the 1 tonne compared with the 2 tonne unit, mentioned the problem of stacking and suggested that transport units could be designed as integral parts of field machines.

J B Holt particularly liked the idea of the transporting box being part of the field machine; he suggested that 1 tonne units could be safely stacked two high using pallets and thought the 1 tonne unit desirable to fit in with tractors and conventional handling equipment.

S A Bradburn (Farmers Fertilizer Company, Royston) observed that five years had elapsed since agreement was reached on the 1.5 tonne fertiliser pallets for safety reasons, such that pallets might be stacked five to six high. There were experiments with 1 tonne loads but boxes had proved unsatisfactory due to slow turnaround.

Dr A D Trapp (Newcastle University) asked if 1 tonne steel containers were likely to become the norm for potatoes; also, how did their costs compare with wood?

D A Bull felt that there would be a gradual movement into bulk containers. The techniques were available now but they needed to be well managed. Costs: Steel containers £90 per tonne, wooden chitting trays £70 per tonne.

R H F Jeffes outlined the use of an Allis roll baler, leaving the bales in the field, coupled with strip grazing, giving a zero handling system.

R Baird (farmer) appealed to manufacturers to provide a decent platform to work on, on a planter.

D A Bull agreed with the need for a platform. The trend for design in the future would be to use tipping hoppers on the back of machines.

T C D Manby (Past President IAgrE) commented that vegetable growers had emphasised that crop handling was their major problem. This had led to the trend for bed production, allowing materials handling vehicles to pass between.

W R Butterworth asked if there were an ideal loader for mixer wagons.

R J Nicholson in reply, said that assuming moderately high tonnages of precision chopped silage, a medium duty fore-loader with a well trained operator would be about ideal. However, weighing devices in the wagon should provide early warning to prevent overload and better top grabs should be designed to give a cleaner "face".

N R Horsham (GRI) enquired about the safety of operators using industrial loaders for filling and unloading silage clamps.

J C Weeks (President IAgrE) pointed out that industrial loaders are not tractors and, therefore, not within the scope of the regulations. However, the 1974 Act was all embracing. The employer must not put himself or his employees at risk. If noise exceeded 90 dB(A), ear defenders should be used.

R Patrick felt that before looking at the problems of handling seed and fertiliser we should be sure that drills were the right drills.

R H F Jeffes used a 3 tonne spreader with a large hopper. He felt it was time he had as good a drill available to him.

P Robinson (ATB) enquired if linear programme decision-making models would one day be available to help practising farmers.?

A G Dumont had little contact with farmers, being more in contact with ADAS. However, the aim of the NIAE Systems Department was to compare different transport systems in economic terms when each system was used under its own set of optimum conditions.

D A Bull observed that computers were precise machines so that, whenever they were used, we must put precise information in if we wanted precise information out.

W E Klinner (NIAE) was of the opinion that improvement on the limitations of the conventional tractor as a mechanical handling tool could be achieved if equipment could be readily fitted to its front end and if its seat and controls could be swivelled up to 180° and two-way operation made possible.

R Baird noted that in the mining industry a lot of equipment had the man facing sideways, thus he only turned through 90° to face forwards or backwards.

K B Francis (Institute of Materials Handling) asked if it were safe to use a fork truck to raise men to work at height for cleaning gutters, etc.

J C Weeks (President) stated that this was permissible if a safe platform were provided.

J R Whittaker (Health & Safety Executive) warned that a guard rail should be provided if working continuously at height. If the person had to climb up, proper access should be provided.

T Snell (Snell Development) asked if closed circuit television had been considered for use on tractors.

J B Holt agreed that it could be useful when reversing long trailers, or for one-man operations. It was currently being used at the docks.

R Arnold (NIAE) felt sure that there must be scope for automatic or remote controls in materials handling.

concluded from page 85

5 Uses of the I/LP model

One example of the use of the I/LP model has been described. By adjusting hours available for specific operations, and/or work rates for a given team, the model can be used to study transport systems under various field conditions.

The development of this model has highlighted the complex problem a farmer faces in choosing a transport system that is best for his farm over a whole year, and under different conditions from year to year. The integer/linear programme is an extremely useful tool which will be able to answer many important questions on transport on the farm.

References

1 **Audsley E, Wheeler J.** The annual cost of machinery calculated using actual cash flows. *J Agric Engng Res* 23 (1978).

2 **Nix J.** *Farm management pocket book,* 7th Ed. Wye College, School of Rural Economics and Related Studies, Ashford, Kent, 1976.

D A Bull was of the opinion that electronics would play an increasing part.

H J Carnall reminded the questioner that controls often need "feel". Remote controls do not provide this.

J V Fox (Bomford & Evershed) enquired why European tractors had a high hitch point for trailers. This presented problems for British trailer manufacturers.

D A Bull felt this was against safe principles.

T C D Manby agreed that this would worsen braking because of greater weight transfer to the front wheels.

J Chambers (retired design engineer) reminded the meeting that in the early days of the 3-point linkage many people were killed using the top link as a hitch point. The high hitch point used on the continent could be lethal.

D R F Tapp explained that the trailer hitch was at the commercial vehicle level. On the continent, trailers are used with both commercial vehicles and tractors.

D R F Tapp asked why Mr Dumont had selected a tractor and trailer speed of 20 km/h, but 30 m/h for the special vehicle.

He also observed that tyres on handling vehicles needed flotation, which attended bigger diameter. Lower inflation pressure reduced soil damage. On the continent, trailers and implements had large, low pressure tyres. Why not in the UK?

A G Dumont explained that 20 km/h was the average road speed for tractor and trailer. The special vehicle would be able to go faster if legal.

H J Carnall commented that suitable tyres were not available. Load ratings drop dramatically with inflation pressures. We needed better understanding of the requirements from tyre manufacturers.

Book reviews

Modification of soil structure

SCIENTISTS from fifteen countries have contributed the 56 edited papers contained in this publication. The papers were originally presented at a special meeting of Commission I (Soil Physics) of the International Society of Soil Science, held in Adelaide, Australia, in 1976, on the subject "Amendments for soil conditioning".

Topics covered include the basic physics and chemistry of soil particles, aggregates and pods, techniques for assessing bulk strength of fields soils and soil aggregates, and assessment of soil bulk density and moisture content.

Bonding agents, structural stability, water flow and infiltration are discussed, as are the effects of compaction on physical properties. The classification of aggregates is related to dam design, tunnelling and water harvesting. Soil structural improvement by organic mulches and soil conditioning materials is reported, followed by mention of water deficiency in grass turf and effects of irrigation on earth-worm ecology.

Finally, developments in minimum and mulch tillage techniques and also deep soil loosening are discussed in relation to their effect upon soil structure, soil shear strength, infiltration and root development.

This book is of interest to specialists in a wide range of disciplines, where soil is a basic working material, ie soil scientists, engineers both agricultural and civil, biologists and agriculturalists. It is not a book for the lay reader as the editors have not attempted to provide each section with general comments and conclusions. It serves as a useful review publication of the latest work in this developing area.

Edited by W W Emerson, R D Bond and A R Dexter, published by Wiley, 1978. *RJG*

Horticultural machinery

HORTICULTURAL MACHINERY is already widely used as a standard text-book for trainees and students taking Stage 1 City and Guilds examinations. The authors' considerable experience in this field is clearly evident in the layout of the book which makes good use of simple line diagrams and photographs. Questions posed at the end of each chapter serve to act as a check on the depth of appreciation of the contents on the students' first encounter with the subject matter and later may be used to determine the need for revision in a particular area.

In drafting this, the second edition, the authors have made two major changes through an extension of the scope of the book to cover nursery machinery, chainsaws and glasshouse equipment and by the introduction and transfer to SI units. The latter is achieved in a manner designed to encourage students to think metric rather than simply convert a perhaps more familiar imperial measure.

Having taken the plunge by extending the scope of the book beyond the needs of the Stage I examinations, the authors inevitably run greater risk of being criticised on choice of material and depth of treatment. It is perhaps surprising to find a chapter on mist propagation, soil warming cables and the like without prior mention of the fixed equipment in glasshouses necessary to control the total environment within the structure. Also Chapter 12 falls short of the general high standard of the book through omission of any reference to power driven harrows, etc for seedbed preparation.

Finally, and on a more serious note, should we expect in the future to see greater stress placed on safety? Should the student be warned of the existence of 3-phase electricity supplies, safe working angles for pto shafts etc?

Horticultural machinery, by M J F Hawker and J F Keenlyside, Grower Books, £4.25 inc p and p.

F B

FBIC Farm buildings and equipment directory

A NEW *Farm buildings and equipment directory* was published in June by the Farm Buildings Information Centre. It replaces the second directory published by the Centre in 1976 and is claimed to be the most complete and up-to-date publication listing 'who makes what — and where' in farm buildings and equipment.

Since the publication of the 1976 directory, trade literature from many more firms has been collected and filed in the Centre's library.

The new directory contains over 3500 products marketed by more than 1100 manufacturers ranging from simple frame structures to package deal controlled environment houses; from specialist finishes for floors and walls to fixed equipment.

The first section lists manufacturers under 178 different product headings. The second lists manufacturers names, addresses and telephone numbers.

The new directory is available from the Farm Buildings Information Centre, National Agricultural Centre, Stoneleigh, Kenilworth, Warwickshire CV8 2LG, price £4.75 including postage and packing.

Education and Careers Advisory Service

In addition to leaflets F51 — F53 (see inside back cover — Volume 33/2) a further introductory leaflet:—

F54 Courses and associated careers in Agricultural Engineering linked with grades of membership of the Institution of Agricultural Engineers.

is now available on application to:—

The Secretary,
The Institution of Agricultural Engineers,
West End Road,
Silsoe,
Bedford MK45 4DU.

West Midlands Branch technical award

HIS report on feed metering in broiler breeding has won the West Midlands Branch Technical award, for 1978, for William Waddilove MIAgrE, of The Hollies, Wolston, Warwickshire.

The report is based upon an investigation of one privately owned farm but points out that the success of any broiler breeding enterprise depends upon producing the maximum number of eggs of the correct quality – to which end accurately controlled feeding of the pullet prior to laying is essential. A drop of as little as 1 lb of feed per day per 100 birds can reduce yield of eggs significantly.

In the days when feed was supplied in 56 lb bags, accurate weighing of the food supplied to each pen of birds was a simple matter. With the conversion to bulk delivery and the estimation of quantity by volume, accurate control is only possible if the consistency, density and "compactability" of the feedstuff are consistent. This unsatisfactory situation led Mr Waddilove to investigate the range of weighing equipment and techniques currently available. He was able to categorise these under a number of headings:

Centralised weighing and bagging, bulk hopper weighing, feed hopper weighing, weighing of an intermediate hopper between the auger outlet and feed hopper, flow weighing.

Flow weighing systems could be further sub-divided into "weighing by momentum", conveyor belt weighing, tipping bucket and rotating bucket (drum) methods. A critical review of all these led to the adoption of the rotating drum technique for installation on the farm in question.

A commercially available unit was installed and tested in one broiler pen and proved to give satisfactorily consistent results. Variation over ten tips was only 1.5%. The unit was equipped with a mechanical counter, an electric totaliser and presentable counter which enabled the number of tips to be programmed.

Delay in the delivery of a second weigher precluded expansion of the system to a second pen in time for useful results to be obtained, but Mr Waddilove is of the opinion that the principle which has been exploited is the correct one and that a significant step forward has been made in the matter of accurately metered stock feeding.

Small advertisements

1978 Autumn National Conference

(In association with Southern Branch)

10 October 1978, starting at 10 30 h, closure approximately 16 45 h.

At: The Lorch Foundation, High Wycombe, Bucks.

Subject: "Specialised Prime Movers in Agriculture"

Conference Chairman:
D N Scott BSc AMIO *Past Chairman National Association of Agricultural Contractors*

Programme:

Paper 1 Horticultural tractors including vineyard and orchard
John Bennett BA
Product Planning Specialist, Massey Ferguson Co

Paper 2 High clearance tractors
Lamar Williams
John Deere, Spain

Paper 3 Large four wheel drive tractors
David R F Tapp
CEng MIMechE MIAgrE
Director, County Commercial Cars Ltd

Paper 4 Forestry tractors
Airlie Bruce-Jones
Director, James Jones Ltd

Paper 5 *Crawler tractors*
H F W Flatters, *formerly of Aveling Barford International Ltd*

Registration forms for members with registered addresses in the UK and Eire were mailed on 18 July 1978.

Members abroad, and any other persons, requiring further details or registration forms should write to the Conference Secretary:

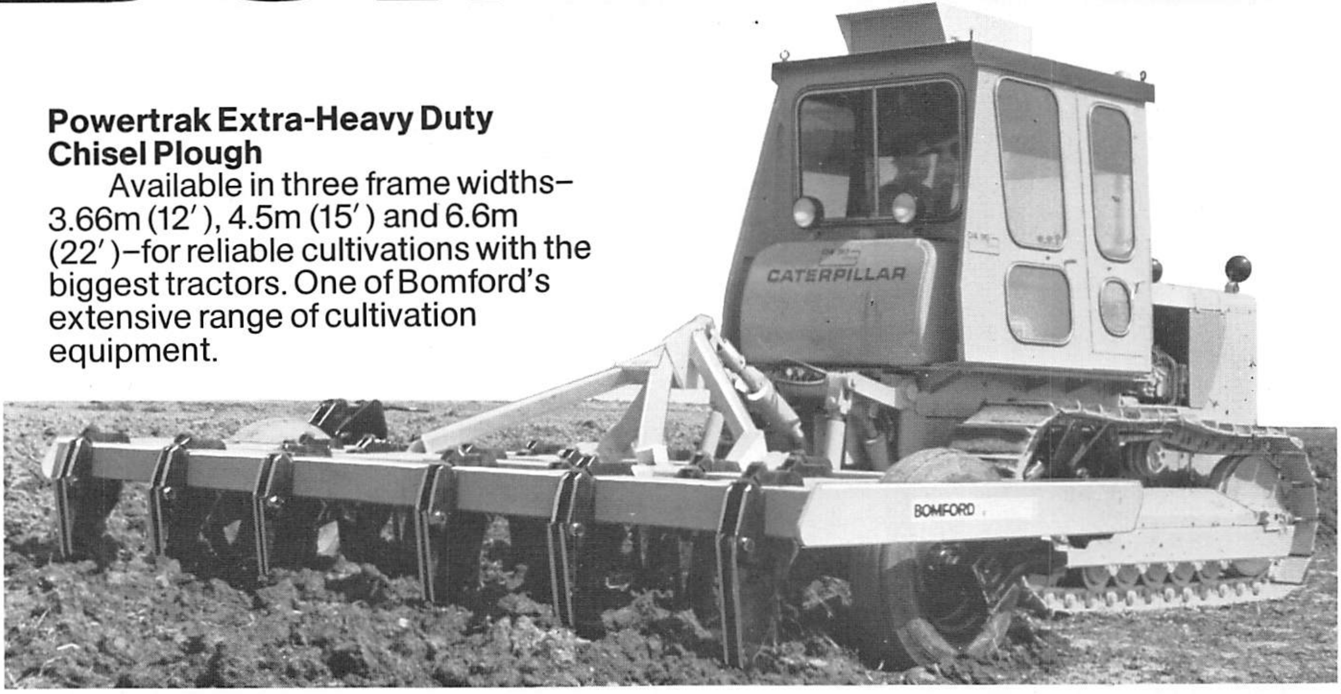
Mrs Edwina J Holden, Conference Secretary, The Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DU Tel: Silsoe (0525) 61096.

The AGRICULTURAL ENGINEER is printed by Studio Trade Plates Ltd, Watford WD1 8SA. All advertising space orders and copy should be addressed to Linda Palmer, Advertisement Manager, The Agricultural Engineer, PO Box 10, Rickmansworth, Herts WD3 1SJ (tel Rickmansworth (09237) 78877).

BOMFORD

Powertrak Extra-Heavy Duty Chisel Plough

Available in three frame widths–3.66m (12′), 4.5m (15′) and 6.6m (22′)–for reliable cultivations with the biggest tractors. One of Bomford's extensive range of cultivation equipment.



Highwayman Flail Cutter

Available with interchangeable heads for fast and economical grass/hedge control and brush/scrub clearance.

From the World's largest manufacturer of tractor mounted flail mowers.

For land or water management choose Bomford.

BOMFORD Bomford & Evershed Ltd., Evesham, Worcestershire, WR11 5SW.
Tel: Bidford-on-Avon (0789-88) 3383. Telex: 311081.