THE AGRICULTURAL ENGINEER

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The AGRICULTURAL ENGINEER is published quarterly by the Institution of Agricultural Engineers
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Cover – A 2200 tonne grain bin – an example of increasing size of installation.

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Grain drying in Britain

Where to next?

TWENTY years ago many types of grain drying equipment were in use on British farms from the humble in-sack drier, through a range of batch driers and continuous flow (crossflow) devices, to the well known ventilated silo. Bulk drying on the floor was in its infancy, being used as a safety valve when harvested yield exceeded expectations or when other facilities could not cope. Research reports were concerned with the effectiveness of batch driers, and with the control of the continuous driers. Fuel economy was hardly considered.

Experiments were being conducted on techniques for drying which did not rely on the use of warm air to heat the grain. Infra-red radiation had been reported, from Italy, as being beneficial in heating the seed and thus increasing its vapour pressure; it then remained for the vaporised moisture to be removed by a draught of air. Other workers beamed microwave energy into beds of cereals where it was absorbed and, again, caused direct heating. The fluidised or "spouted" grain bed was tried, it being said that by this means the boundary layer of static air around the seed was minimised so that negligible heating was required to assist moisture transfer. Drying agents such as silica gel were considered, as means of removing moisture from air which was then passed through the grain, the improved vapour pressure difference between the grain and air resulting in rates of drying better than those achieved by using ambient air.

It is interesting that these, and a few other techniques, met with some success in laboratory and small scale trials, but have never found favour in farming practice. One does not have to look far for the reasons: simplicity in both design and operation of equipment are important; reliability and simplicity often go hand in hand. An obvious attraction is a system which is easily understood and controlled by an operator, whose attention should be concentrated on keeping in step with the incoming loads of wet grain.

Recently the British cereal harvest has increased enormously, wheat and barley output having doubled since 1960. The trend is towards large cereal acreages, so large scale, effective and reliable drying facilities are in demand. The smaller farmer, in the main, is adequately equipped. Storage drying on the floor has proved particularly popular, although a couple of difficult years, when large yields of very wet grain were harvested, have led to improved order books for the manufacturers of continuous flow driers. But these techniques use warm air — air which has been heated by fossil fuel, and at a time when energy supply must be considered closely. The primary requirement is still to dry the grain to a safe level, but this can no longer be done regardless of cost. Furthermore, increased grain output implies either greater throughput from continuous driers or larger quantities being dried on the floor — or both. Accordingly the emphasis now must be upon very close control of drying conditions: that is to say, careful attention to the quality and uniformity of the product. Profit margins are not large, and these should not be put in jeopardy by inadequate supervision of driers, or by inadequate instrumentation so that the farmer is tempted to remove "just one more percent for safety". Systems must be designed, instrumented and controlled so that there is no danger of insufficient air supply arising from overload of drying floors, no danger of damage to germination of seed grain by overheating in high temperature cross-flow units, and as little danger as possible of significant moisture gradients existing in the allegedly dried material. Instrumentation for driers exists but is not yet comprehensive. There is still scope for making mistakes — for example by the ill advised use of heat when dealing with beds of very wet grain in "floor driers".

So how can the agricultural engineering industry help the farmer in the future? That is to say, how can present knowledge be put to good use in the design and operation of driers which are economical of energy use, reliable in operation and which ensure maintenance of grain quality? Can we look for solutions in the application of the all-powerful microprocessor to the control of existing driers, or should we be considering revolutionary designs? Is there an alternative to the continued use of fossil fuel — perhaps solar heating can be employed? Or indeed, are things satisfactory at present, so that we should leave well alone?

There are, of course, several answers to these questions. Clearly the industry is already equipped with driers which do a reasonable job of work. A lot of thought has been given to grain handling, to control of dust and to the reclamation of waste heat. Moisture content of the dried product can be automatically controlled, in the case of high temperature driers, by simple but reliable temperature measuring devices in the emergent airstream. The grain from a well-managed drying installation will not have been damaged by the process of moisture removal.

So perhaps the first emphasis should be upon management of the drying unit and, to this end, conferences such as the one held by RASE and ADAS at the National Agricultural Centre in November 1979 makes an important contribution. Speakers from the manufacturing industry, from research stations, from the university sector and from ADAS itself combined to present a fascinating review of the national grain situation together with useful background theory and sound practical advise on the running of drying and storage units. And a little crystal gazing encouraged farmers and drier operators to consider "what might be". Ministry publications, too, make good reading, and the recently issued Booklet 2137 *How much heat do you need* provides a ready made lesson in management of on-floor driers.

But looking further ahead, can we expect to see improvements in continuous flow drier design? The standard textbooks point out the advantages of co-flow and contra-flow driers. The co-flow principle allows the use of high temperature air, but at the same time yields grain which has been uniformly dried and which has not been damaged by overheating. Contra flow of air and grain again yields a uniform product, with the air emerging at almost the temperature of the incoming grain: hence good use is made of heating fuel.

Research into the mathematical simulation of the grain drying process has been speeded by the advent of the digital computer. It is now possible to predict, with reasonable accuracy, the performance of many types of drier — whether they be existing models or new designs which have not progressed beyond the drawing-board stage.

Perhaps, then, we can look towards the application of these mathematical techniques to the "computer design" of a new generation of continuous driers — and a reappraisal of some of the older ideas which fell by the wayside 15 or 20 years ago?

In the meantime, microelectronics *is* of assistance, particularly in the measurement and control of conditions in floor driers, and further developments are anticipated in the near future.

And the energy situation? It can be seen on page 7 of this issue that the use of straw as a tuel is well under way at Nottingham, and even as far north as Edinburgh (SIAE) there have been successes in the drying of grain by solar energy. But for the present, these alternatives are not really viable on the farm. However, the future holds an interesting and encouraging prospect.

BCS

Presidential Address

Mr J C Turner will make his Presidential Address "AD 2000 – Survival and Success", at the Allesley Hotel, Allesley Village, near Coventry on Tuesday 13 May 1980, on the occasion of the Institution's annual conference.

Field sprayers

H J Nation

Introduction

FROM a position of relatively minor importance occupying only a few weeks in the farming calendar the spraying operation has moved in only a few years to become one of the major inputs in an arable system. The agrochemical companies have been continuing with their research and development work but the stringent requirements to be met and the steeply rising costs have meant that fewer new materials have been coming forward, though re-formulations and mixtures have helped to maintain the number of new products. On the machinery side, after many years of modest activity, there has been an outburst of development with very many introductions of new models and new concepts. Probably in no other sector of agricultural machinery have such vast strides been made in a short time.

It is not long since the majority of sprayers on UK farms were small and of elementary design, representing an investment of perhaps as little as one-tenth of the cost of the general purpose tractor with which they were used. It can be said, too, that often the regard in which the spraying operation was held and the care taken over it and of the machine were commensurate with this. Now, the equivalent sprayer may cost one quarter of the price of the tractor and many more types and sizes are available at prices up to and above those of tractors. Indeed, the largest and most sophisticated sprayers are now approaching the cost bracket of large combines. What changes have taken place in the design, performance and use of sprayers to justify their new position in the league of farm machinery? Possibly because combines can be seen to be putting money into the bank there has been less difficulty in selling them at high prices, whereas there is a psychological resistance to paying high prices for sprayers which are concerned with spending a lot of money, the effect of which is not immediately apparent.

Certainly the continuing steep rise in the spray chemical bill, through both increasing use and price rises, has made it easier to justify a greater expenditure on the equipment whilst the goal has been ever-higher yields and returns. Ten to fifteen years ago cereals treated with agrochemicals costing more than £2 — £3 per hectare would have been the exception rather than the rule, whereas in the present situation, with successive treatments for different purposes, it is not unusual for chemical costs to exceed £100 per hectare. In one year a sprayer may distribute chemicals costing up to 10 times its own purchase price. At this level it is vital that the most effective use should be made of these materials. In the future there may be some change of emphasis, with reduction of input for a maintained output assuming more importance, rather than even higher outputs remaining the objective.

Developments have been taking place in almost every possible aspect of sprayer design and construction. There has been an increase in diversity of types of sprayer; many developments have aimed at increasing overall working rate or at improving performance and yet others have had the object of improving the effectiveness of the machine on the field and timeliness of application.

H J Nation is from the Spraying Department, National Institute of Agricultural Engineering.

Types of sprayer

The maid-of-all-work since 3-point hitches became common has been the mounted sprayer. The main changes here have been a steady increase in size — both of boom length and tank capacity, in boom design for increased strength and stability, in the trends towards diaphragm pumps and their mounting on the sprayer instead of on the pto shaft and in tank construction, where plastics has replaced metal except stainless steel and shapes have changed to improve agitation or to keep the centre of gravity as near as possible to the tractor.

There have been greatly improved sales to farmers of those types of sprayers which were originally almost exclusively used by contractors. Trailed sprayers conceived originally as a means of using a large tank have been considerably developed, though there has been less need to increase the size of the tanks; indeed, several models of trailer have appeared with smaller tanks. Self-propelled sprayers based on conventional or high-clearance tractor units are also being sold in increasing numbers to farmers and some of these are being equipped with very long booms. Finally, sprayer units mounted on road/cross-country vehicles which have been very popular with contractors for their high mobility are also now in demand from farmers, particularly those with two or more separated holdings.

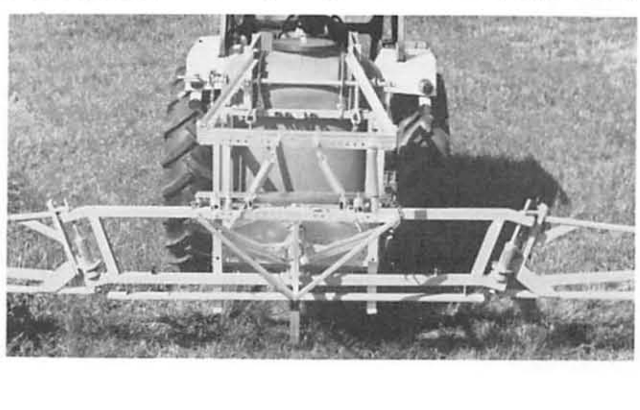
The use of high-clearance tractor units was mentioned. These provide the under-body clearance to permit spraying through tall crops. This type of operation, which has come into prominence particularly with the large amount of oil-seed rape now grown, has also imposed the need for spray booms to be adjustable to greater heights than formerly and this provision is now being made on most types of sprayer.

Many models of sprayers, particularly at the upper end of the size range, are available as dual-purpose machines — that is, suitable for application of liquid fertilizers as well as agro-chemicals. A recent development has been the additional provision of means for spraying suspension fertilizers, this usually involving a special set of plumbing of large bore with heavy duty nozzles.

Improved performance

For many years the variability in the deposit of spray over the target area during typical farm spraying has been a matter of concern. The effectiveness of the chemical could presumably be considerably improved if the wide variations — typically, from less than one-quarter up to several times the intended dose, when assessed over small areas — could be reduced, (Hebblethwaite, Richardson, 1966). Early in the programme of work in the NIAE Spraying Department on field sprayers the main cause of these wide variations in deposit was identified as the random movements of the sprayer boom. Studies showed how variation in height of the extended parts of the boom could result in uneven deposit because of incorrect overlap of adjacent sprays. Also the forward and backward whipping of booms, causing the speeds of the nozzles over the ground to vary considerably could also result in very uneven distributions, particularly with fan sprays (Nation, 1968).

Studies of the behaviour of booms of different designs and of several boom suspension systems showed that boom stability could be dramatically improved if a boom were mounted on a sprayer by a means that provided some flexibility and isolated the boom from the rapid rolling and yawing motions of the sprayer frame.



The NIAE gimbal boom mounting – the boom is supported at its centre through horizontal and vertical pivots and restrained by pairs of springs and viscous dampers in each plane of movement

A mounting system developed at NIAE achieved this by having two pivots — vertical and horizontal — passing through the centre of the boom. The boom was restrained by springs and prevented from oscillating by viscous dampers (Nation, 1977).

Later, commercial interest in providing more stable booms was first shown in the use of pendulum-type suspensions. By hanging the boom from a single pivot above the centre the object was that the rolling motion of the sprayer should be experienced by the boom only as a sideways translational movement without any turning. This has been moderately successful with some fairly long booms, and theoretically it should be more effective with these than with short booms. With this type of suspension the centre section of the boom is usually arranged to swing between guides.

Some of the commercial developments have involved the use of pairs of inclined links. When a boom is suspended on a pair of links which converge upwards the effect is similar to that of a single point pendulum, for small displacements. However, this system, in which the trapezium distorts sideways with the rolling motion is even more effective in reducing the transmission to the boom of the rolling motion.

When such a pair of links is arranged to converge downwards they have a rather different property. The restoring force tending to return the boom to its rest position relative to the sprayer frame is very strong and this can be put to advantage in a practical situation.

When a sprayer equipped with a boom suspended as a pendulum from a single pivot is driven across a side slope the boom will normally be horizontal and not parallel to the ground. Such a boom can be made to adopt the required sloping attitude either by moving the effective centre of mass of the boom to one side or by shifting the pivot point on the boom sideways: the latter is the most popular method. Similarly when twin links are used converging upwards, on a side slope the boom will adopt a slope intermediate between that of the ground and horizontal. In this case, either a hydraulic ram, springs or other means are brought into play to bias the boom sideways the required amount or a locking device is provided to make the link suspension inoperative. However, when the twin links converge downwards the restoring force is so strong that the boom will remain aligned to side slopes whilst still retaining its isolating function against rapid rolling motions.

In most of the commercial developments the booms swing between guides and these transmit to the boom the yawing motion of the sprayer. Recently NIAE Spraying Department has shown how a twin-link suspension can very simply be arranged to provide the necessary isolation in yaw by the use of universal joints at each end of the suspension links and a form of restraint at the centre of the boom (Nation, 1978 [ii])

When spray booms are suspended in such a way that errant movements with respect to the ground are reduced to the minimum, improved spray distribution and possible reductions in dose and application rate which may follow are not the only advantages. The reduced chance of boom tips striking the ground means that higher forward speeds are possible or longer booms can be used, both contributing to a higher work output. Alternatively, with appropriate choice of spray angle or adjustment of nozzle spacing, booms can be set closer to the target, leading to improved penetration of spray through a crop canopy and considerably reduced risk of spray drift. This aspect is particularly important in the context of the reduced application rates now receiving more attention. Finally, since such stabilizing mountings reduce the transmission of high accelerations to the boom, the structure would be less highly loaded, less subject to shock fractures and can be lighter.

The Monotrail hydrostatically propelled gantry sprayer of Mr D Dowler which spans a 12 m swath providing good boom stability and simple and accurate swath matching

The Atlas low-ground pressure-sprayer of Cleanacres Limited with eight low pressure tyres

Many interesting developments are to be found in the sprayers built by farmers and contractors incorporating features which they consider to be important in their own situations. Some of these appearing recently have included means for improving spray boom stability. A particularly noteworthy example is the gantry-type machine called the Monotrail and developed by Mr David Dowler of Pillerton Priors. With a wheel at each end of the 12 m span structure, perhaps the ultimate in boom stability is provided.

Sprayer use and operation

One of the most significant developments in sprayer use has been the extension of the spraying season from the traditional six weeks in the spring. Now spraying may take place at almost any time of the year but the increase in autumn and winter spraying of cereals is particularly important. This, more than any other aspect, has lead to a re-examination of the whole concept of the sprayer, stemming mainly from the need for autumn spraying of winter cereals forcing an interest in low ground pressure vehicles.

The well-known Argocat, in its eight-wheeled version, has been adapted to spraying (Cussans; Ayres, 1978). A similar, but larger, vehicle developed originally for military purposes is also available as the Atlas (All-terrain lightweight application system). The Lightfoot, a more conventional four-wheeled vehicle, recently introduced as a self-propelled sprayer, also has a low ground pressure. Over-sized tyres are being fitted to other machines with the object of achieving lower ground pressures.

The Willmot Lightfoot-sprayer – an example of a self-propelled sprayer with vehicle suspension

At the present time there is intense activity in the application of monitoring and automatic control equipment in spraying. The basic measurements made as inputs to both types of systems are of the forward speed and of flow rate to the spray boom. The object with the various types of monitoring equipment is to provide a constant indication to the operator of any error occurring from the intended application rate so that, by adjustment of forward speed or spray output, he can maintain the target rate more accurately.

Automatic control of application rate has been available and in use on some sprayers for many years — the Dorman Regu-flo is an example. These systems depend upon a fixed relationship existing between pump delivery and forward speed and this is valid with a pto driven pump, provided that the same forward gear is used all the time. Recently systems have been developed which are not dependent upon the gear selected but accept a signal of forward speed and maintain flow rate to the boom in relation to this. Flow is adjusted by operation of a pressure regulator, by adjustment of pump speed or by changing the displacement of a fixed speed pump. On some trailed sprayers a variable displacement pump is driven by one of the sprayer land wheels, so that pump speed is always in direct proportion to

The jockey wheel picking up ground speed from the tractor rear wheel to provide automatic control of application rate with the Tecnoma AR 160 Autoregulator

forward speed and different application rates are obtained by adjustment of pump displacement.

The advent of tractor cabs and in particular the Q-cab has accelerated the application of remote control of the various sprayer functions. Hydraulics or pneumatics are used for powered folding and unfolding of booms and for boom height control; electric solenoid valves are being increasingly used for turning spray on and off and for switching boom sections on and off. Remote control of spray pressure is now becoming more common with a pressure gauge near the control panel, but usually outside the cab, indicating the pressure in the boom. By reducing the operator's burden of the more physically demanding and irksome tasks it is hoped that more attention will be given to ensuring that everything is functioning correctly and that a good job is being done.

To the same end, attention has been given to aiding the operator in obtaining more accurate matching of successive swaths. As booms have increased in length, spraying speeds have been creeping up and timeliness of application has been assuming more importance, swath matching has become more of a problem. Following a survey some years ago of the methods then in use and the accuracies being achieved, the foam blob marker was selected as being worthy of improvement (Lawrence, 1973). For mounted sprayers with booms up to 12 m the major change suggested was in the use of mirrors on the tractor bonnet and at the boom tips to improve the view the operator has of the foam blobs. With this periscope arrangement the operator sees in his straight-ahead vision a view of the line of blobs seen from the boom tip. He is thus able to position his unit with a high degree of accuracy. For longer booms and trailed sprayers other methods of conveying to the operator an indication of the position of the boom tip relative to the foam blobs have included photo-electric detectors, (Butterworth, H M; Butterworth, W R, 1979) and closed circuit television with small cameras at each boom tip and a monitor screen in the cab (Lawrence, 1978).

The tramlining techniques which have been used increasingly over the last few years are the major alternative to the various marking systems. The establishment of tramlines transfers from spraying to the drilling operation the additional concentration necessary to ensure accurate driving. Some prefer not to introduce this additional complication at drilling time. Where it is well done, however, the subsequent spraying operations are considerably helped.

Management and logistics

A survey carried out in 1976 by ADAS highlighted the serious effect on overall spraying output of a badly managed spraying operation, particularly in the context of water supplies (MAFF, ADAS, 1976). Examples were given showing how wasteful it was of the limited spraying opportunities for sprayers to travel long distances back to farmyards to be refilled, or to be filled very slowly from hosepipes. If travel distances are not great a considerable improvement in output can be obtained by filling the sprayer by gravity through a large bore hose from an overhead tank. For remote fields it would be better to take the water to them in tanks carried high enough on trailers to fill the sprayer by gravity or to use bowsers.

Over and above such sensible provisions as these, reductions in application rate can make very useful contributions to increasing output (Nation, 1978 [i]). This has been one of the main arguments in favour of CDA (controlled drop application) with which the application rate may be as low as one-eighth of that with conventional nozzle applications. However, results of field trials of CDA have indicated that more work remains to be done before the limits circumscribing the situations in which this method is satisfactory have been adequately defined (Bailey, 1979).

A swath matching aid – angled mirrors at the boom tips forming periscopes with a pair of mirrors on the tractor bonnet to improve the driver's view of the row of foam blobs

Commercial machines — the Horstine Farmery Microdrop — and experimental equipment have used as their spinning discs for producing the spray the serrated-edge discs of the Micron Herbi hand held sprayer. The flow rate that these discs can handle is very small and acceptable forward speeds for field machines have been obtained only by stacking-up these discs on each unit spindle (Cussans; Taylor, 1977). NIAE work has shown that smooth-edged discs can handle flow rates up to ten times that of the Herbi disc by employing a mode of drop formation from ligaments leaving the disc edge in contrast to the direct drop formation from the edge of a Herbi disc (Frost, 1978). Commercially this higher output has been achieved in the Micron Micromax spinning cup by similar ligament formation.

Such spinning disc equipment, which has been developed for herbicide applications, results in a spray in which all the drops are in a very narrow size range around 250 micrometers (µm) — although there may be a minor proportion of smaller satellite drops. Under ideal conditions at an application rate of 35 l/ha, there would be 43 drops/cm^2 but because of the variability of deposit for various reasons this population could be less than 10 drops/cm^2, which may be insufficient for adequate performance with some materials, particularly of the non-translocated types, and may partly explain some of the inferior results with this system.

In many of the field experiments, comparisons have been made not only with conventional nozzle applications at rates of 220 l/ha but also with similar applications at rates as low as 60 l/ha. The results with these low rates were certainly very interesting and with more stable booms capable of use nearer the target when their performance should be even better and with a logistic advantage approaching that of CDA, they may be the main competition for CDA (Harris *et al* 1978).

One reduced application rate system is already commercially available — the Ciba-Geigy 7-gallon System (almost 80 l/ha). Although at the moment this is only for pre-emergence applied materials there is certainly the prospect of its use being broadened. The reduced application rate is obtained by a halving of the operating pressure and nozzles are available which will perform satisfactorily at this low pressure. One result is a coarsening of the spray and the effect of this in other than the soil-applied situation will have to be examined.

Prospects

For a combination of economic and environmental reasons the reduction of application rates and total amount of chemical applied must continue to receive serious study. One of the most exciting possibilities is the application of electrostatics to field spraying. There has been work at Sheffield University (Hopkinson, 1974) coupled with field trials at Rothamsted (Arnold, 1979). ICI Plant Protection Division has recently publicised the work there on developing the Electro-dyne hand-held electrostatic sprayer (Coffee, 1979) and NIAE have some current studies on this subject (Byass *et al* 1979).

The progressive adoption of application systems involving lower rates will influence the design of the sprayer, and the use of higher forward speeds and lower ground pressures will become much more common. More stringent environmental and health requirements (Weeks, 1978), will result in attention again being directed to the reduction of spray drift, in the reduction of chemical input rather than the drive for even higher yield assuming more importance and in the development of chemical handling systems which subject the operator to reduced hazards.

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Letters to the Editor

Small tractors

FURTHER to the correspondence in THE AGRICULTURAL ENGINEER, Vol 34 No 2, concerning the recent Small Tractors conference, I have received the following letter from Dr R Wijewardene which I should be pleased to see published.

Many of his comments are of course valid. Perhaps this country should consider providing adequate funds for developing these low-energy concepts.

J KILGOUR,
NCAE, Silsoe.

•

I NOTICED your observation in Volume 34 No 2 of THE AGRICULTURAL ENGINEER, "..... other workers, notably R Wijewardene, have not yet managed to show conclusively that there are real alternatives". Perhaps seated some 6000 miles away from the scene one might be forgiven a hazy perspective — often blurred further by the understandable bias of the export salesman.

The enclosed copy* of a recent paper may be of interest. A dramatic increase in "no-till" farming here — on large farms in the north, — on small farms in the south are mute evidence to the happening of a quiet revolution. This paper was presented on the invitation of the ASAE.

And do you not think that the implication of the next paragraph "So that those able to develop the design concepts ...." is a little fanciful, particularly after the appalling record of energy indulgence not only in farming, but also in a great many other aspects of 20th century life.

A notable feature of March 1978 conference was the absence of anyone with any real *experience* of tropical farming. I realise there was the usual range of professors and salesmen each giving his own views on a situation thousands of miles away; a situation which is peeked at occasionally during a brief visit to confirm pre-conceived perspectives. But how many had actually grown even one complete tropical crop-cycle?

I feel it is time the Institution's members cast their eyes and ears and experience further afield rather than continue talking among, and to, and at themselves. The same record, ... the same groove.

I too once deluded myself as to the role of the plough; .... of the tractor. Experience has taken me beyond that plane. I now have a far clearer picture of the scene and am not a little aghast to realise that far from resolving the prime problem of shifting cultivation, the tractor-and-plough have contributed to aggravate it! Large scale shifting cultivation, as is evident on hundreds of conventionally mechanised farms all over the LDC's ...... Perhaps the intention was good; ... but the results were disastrous!

RAY WIJEWARDENE,
Agricultural Engineer Farming Systems Program, IITA, Ibadan, Nigeria.

**Ref: Wijewardene R. ASAE paper 78-1511. Systems & Energy in Tropical Farming, Dec 1978.*

Electronics in Agriculture

IN recognition of the increasingly important use of electronics in agriculture the Institution of Agricultural Engineers, in association with the Institution of Electrical Engineers, has arranged a conference, "Electronics in Agriculture", to take place on 25 March 1980 at the University of Newcastle upon Tyne. The morning session will be devoted to electronics and the dairy herd, this being the application of greatest commercial development and competition. During this five paper session the requirements of the dairy herd will be described and followed by accounts of three different commercial approaches to the application of electronics; the manager of an EHF will then describe some operational experience. It is felt that this format will encourage a lively discussion between suppliers and those farmers who own such systems or who are considering their installation in the future.

The afternoon session will consist of four papers covering a broad spectrum of applications including field machinery, psychrometry, environment control and some crystal ball gazing for possible trends during the next five years. The discussion will give opportunity for comment upon the hardware which will become available during the next few years and perhaps influence the way in which this technology is applied to agriculture. An exhibition of equipment described by many of the speakers will give delegates the opportunity to assess the reality of the technology and to discuss, outside the conference hall, their problems and ideas with interested parties.

Whole crop cereals: a low-cost approach

B Wilton, F Amini and I Randjbar

Introduction

RESEARCH and development into several aspects of the harvesting and treatment of whole cereal crops has been in progress at Nottingham for ten years. In early 1978 this work was reviewed in an article in this Journal[1] and some of the possible advantages of the system over conventional combining were outlined. The main items of equipment used at that time were a precision chop forage harvester, tipping trailers, a rotary drum drier, a rotary drum separator and a straw-fired furnace (linked to the drier). While there are undoubtedly potential advantages to be gained from operating the whole crop system in this form there are also important drawbacks, the main one being that it includes an expensive drier of a type not commonly available on farms.

An attraction of the system for those who already have such plants is that cereal crops are ready for harvesting at a time when there is frequently a lull in the grass and lucerne drying season; in these circumstances cereals can provide a means of increasing plant utilisation for little additional expense. Although the opportunity to process a different crop must surely be considered favourably by existing operators of crop drying plants, it is thought unlikely to have a significant influence on decisions about investment in new plants.

Commercial activity in whole crop cereal harvesting, drying and processing at present appears to be limited to one Swedish company, Kockums Construction[2]: the company has a pilot plant and has installed at least one commercially-operated plant in Scandinavia. High-output harvesting, transporting, drying, separating and processing equipment is available, the cost and capacity being such that plants are more likely to be owned and operated co-operatively than to be installed by individual farmers. The drying and processing of other materials such as green crops or industrial by-products (for example sugar beet pulp) will almost certainly be linked with any such plant.

It is debateable whether cereal harvesting systems based on relatively expensive drying plants will ever account for anything other than a minor fraction of the crop. There is always the possibility, however, that some new process or demand emanating from the chemical industry may make cereal by-products much more valuable commodities than they are today. If this situation arises and if off-farm separation and processing operations are the most appropriate means of meeting the demand, such plants could become common. Any developments of this kind would have a profound effect on our accepted system of harvesting — probably much more so than the introduction of new 'rotary' types of combine or the more widespread acceptance of various techniques of chemically treating the crop and ensiling it.

Against this background it was decided to examine the possibility of separating the chopped whole crop into various fractions without first drying it, for it was thought that if this could be done relatively cheaply it might make whole crop harvesting and utilisation more attractive to the individual farmer. It was also thought that it might be possible to burn some of the undried straw to provide heat to dry grain in a conventional grain drying system.

B Wilton FIAgrE is a lecturer in the University of Nottingham Department of Agriculture and Horticulture, School of Agriculture, Sutton Bonington, Loughborough.

F Amini and I Randjbar are postgraduates in the University of Nottingham Department of Agriculture and Horticulture.

Separation

It was known from our earlier work that the type of separation mechanism used in a combine harvester would not perform particularly well when fed with dried, chopped whole crop and that when the crop had a moisture content of more than some 20% the separation was completely unsatisfactory. As a first step in the search for an alternative method of separating undried crop the inclined rotary drum sieve mentioned earlier[1] was used: although this was found to give an acceptable degree of separation the rate of work achieved with this machine was low and it was obvious that this approach was not worth pursuing. Pneumatic separation appeared to be the only remaining possibility.

There are many possible configurations of pneumatic separator, and of these two have been extensively studied by other workers with a view to incorporating them into combines. The first involves introducing the material into a vertical airstream which is controlled so that the grain is able to fall while the remainder of the material rises[3]. The second involves passing the crop in a thin stream at high speed through an area in which air is moving rapidly across the direction of crop flow: the aim is to deflect the path of the leaf, chaff and straw components away from that of the grain so that they can be collected separately[4]. Both approaches have their attractions, one being that they can be made to be relatively compact and so they are potentially suitable for mobile operation as part of a combine; however they also have drawbacks.

Once the decision to move to a static separating plant has been taken compactness is of much less importance. Three possibilities which immediately come to mind are:

(i) to use a series of cyclones;

(ii) to feed a thin stream of the crop into a large chamber in a substantially horizontally direction, the expectation being that the grain would travel further than the straw;

(iii) to drop a thin stream of the crop into a horizontal airstream.

It was thought that the last of these was the most attractive in terms of cost and minimisation of grain damage, and that it would certainly be easier to accelerate air, by using a fan, than to accelerate the crop to a velocity that would give adequate horizontal separation.

Hand separation of chopped crops was used to establish the frequency distribution of typical components, and then the behaviour of individual components and mixtures of components was studied in a parallel-sided horizontal wind tunnel. Air velocities of 3 to 6 m/s were used and the horizontal displacement (up to 4 m) during a drop of 0.76 m was measured.

The degree of horizontal separation between grain and the other components was such (see fig 1) that it was decided to build a tapered wind tunnel, complete with continuous mechanical feeding and collection equipment. The layout of the separator is shown in fig 2, the tunnel being 3.0 m long and 1.5 m high and increasing in width from 0.4 m to 1.2 m. The settling chamber has a volume of 12 m^3 and air is moved through the tunnel by a 0.6 m diameter axial flow fan. Limited amounts of material were fed through the separator in 1978: in 1979 an investigation of its performance on crops of wheat and barley chopped in various ways and at a range of moisture contents was made.

When set and fed correctly output A is grain which would be suitable for on-farm use but which would need to be further cleaned for sale. Flap F is positioned so that no grain can be found in output C: the majority of the material emerging from C is 'heavy' straw, ie lengths of straw from the base of the crop and pieces which include a node. Outputs D and E are two 'light' fractions which would probably be mixed and used for feeding.

As expected output B (usually 10-15% of the total) is the least identifiable one, consisting of some whole, normal-sized grain, all the light and broken grain, some

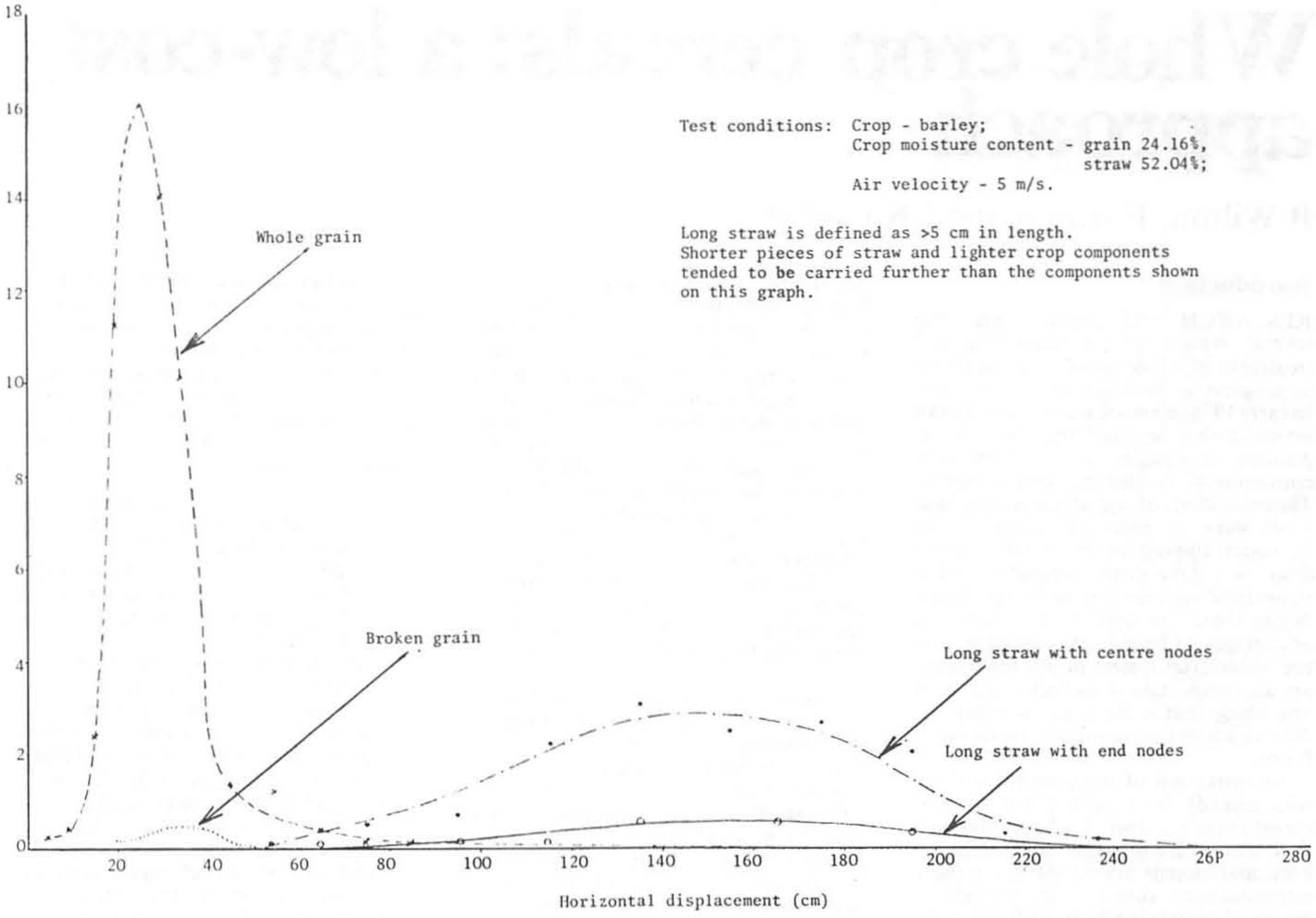


Fig 1 A typical crop component distribution pattern established in wind tunnel experiments·

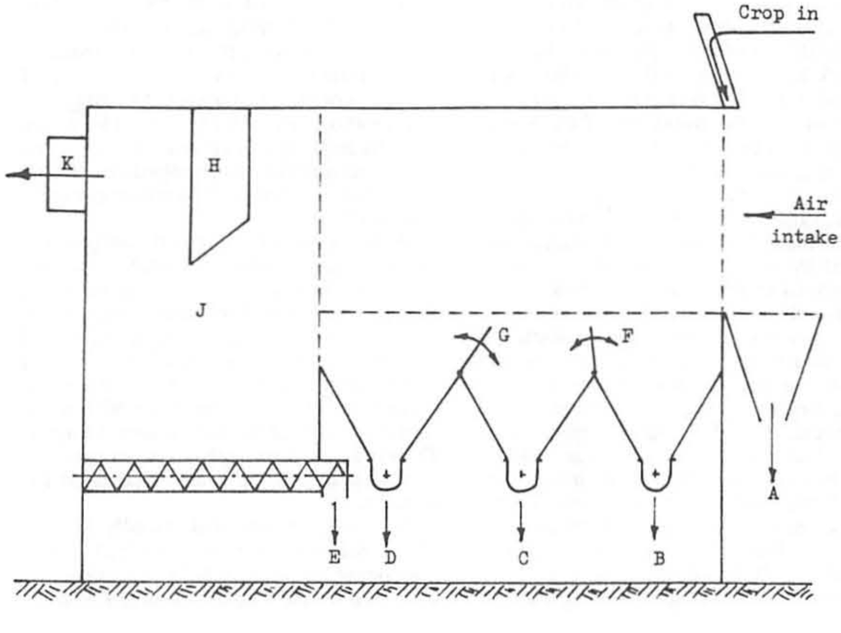
'heavy' straw and nodes which have only short pieces of straw attached to them. Several options for the further treatment, separation and use of this mixture exist:

(i) it can be fed through the separator again;
(ii) it can be added to outputs D and E;
(iii) it can be fed through some other type of separator and the separated components can then be added to the most appropriate of the other outputs.

We will follow up option (iii) but a farmer may well choose option (ii).

Fig 2 The tapered wind tunnel separator

A, B, C, D, and E – Outlets for separated components
F and G – Adjustable flaps
H – Baffle
J – Settling chamber which is emptied by chain and scraper into auger
K – Extractor fan



Utilisation of the separated crop

When working on an on-farm system eventual on-farm uses must be catered for: conventional harvesting systems give

Collecting trays showing separation of grain and straw

two products — grain, which may or may not be required to germinate, and straw which is largely used for either feeding, bedding or, increasingly, as fuel. To compete with the combine any alternative system must also endeavour to meet these demands and, if possible, offer additional benefits. Just how far a whole crop system will meet these requirements is not yet fully established.

There should be no problem in producing feed grain, but preliminary work has shown that grain germination can be adversely affected, particularly by very early harvesting with a forage harvester. If grain with a high germination capacity is required the solution to this problem may be either to wait until the grain has dried down to 20-22% moisture content, to modify the harvester to minimise damage, or to follow up both of these possibilities.

The demand for straw for feeding should be relatively easily met by the whole crop system, provided that early indications that damp straw can be ensiled satisfactorily with a chemical preservative are confirmed. The 'light' fractions have a higher digestibility than baled straw because they contain all the fine leafy material which emerges from the combine, only to be covered up by the long straw from the combine's straw walkers. Baling fails to collect this higher quality material. A number of experiments have been carried out in which sealed bags of light fraction material, mixed with various alkalis, were buried under sand for up to three months (to simulate ensiling). These have indicated that caustic soda used at a rate of 6% of the dry matter was the most effective treatment in terms of both increased digestibility and minimisation of spoilage, and that a crop moisture content of 40-50% is ideal for this method of storage.

In order to achieve accurate dosing of caustic soda a 10 kg batch weigher/mixer for the light fraction has been constructed. The weighing hopper, which can hold about 1 m³ of material, has a hinged bottom which discharges into a 2.5 m-long horizontal mixer. As the hopper trips, caustic soda solution is pumped through eight anvil nozzles mounted in line above the enclosed mixer. Currently the moisture content of each load of the crop is determined at intervals and the pump timing system controlled manually, but it is hoped that some automatic mositure monitoring equipment will eventually be installed to control the caustic soda pump and, if it is thought to be justified, a water dousing pump mounted in parallel.

The 'heavy' straw fraction is perhaps the most difficult material to deal with. If harvesting and separation take place in dry conditions, ie when combines can work, straw moisture content may be as low as 18-20% and it will either burn in a stepped grate furnace[1] or can be stored without problems for later use. If, however, harvesting takes place very early or in wet crop conditions, straw moisture contents up to 50% will be encountered. In this condition straw will only burn slowly and it will not store.

A solution to the combustion problem, which also overcomes doubts about the

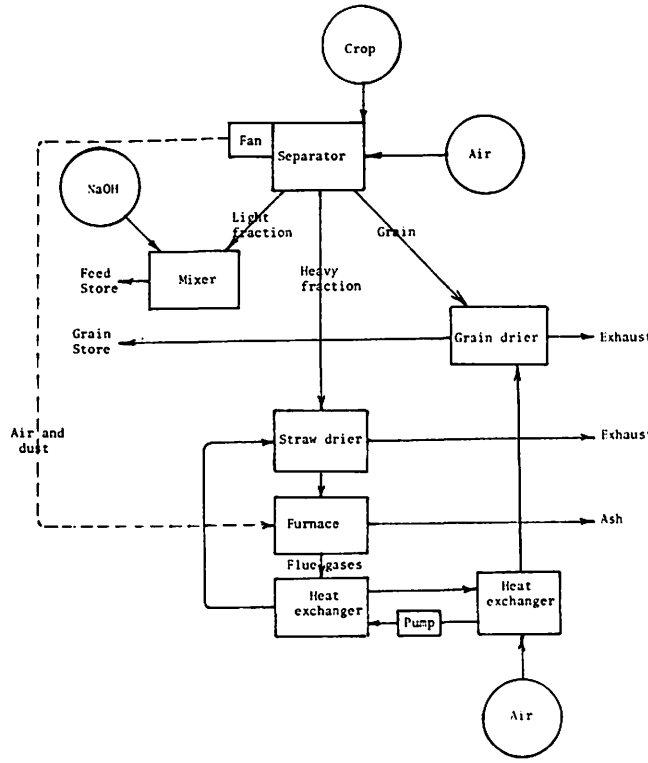


Fig 3 Showing how the furnace and heat exchangers can be linked to the separator

advisability of using flue gases to dry grain, has been found. Two water-filled heat exchangers and a simple conveyor drier have been constructed and added to the furnace as shown diagrammatically in fig 3. By adopting this arrangement it is possible to produce clean air at temperatures up to 80-90°C and to utilise the lowered-temperature flue gases to pre-dry straw for burning.

It is possible that surplus straw could provide bedding, but it is probably more realistic to assume that if large quantities of bedding straw are required it would be sensible to restrict harvesting to relatively dry crops.

Discussion

Combine harvesters have dominated the grain harvesting scene for more than a generation and they have transformed cereal harvesting from a laborious task into a highly mechanised operation which, when conditions are favourable, can proceed at a high rate. Vast sums of money have, however, been spent on their development, on manufacturing facilities to produce them and on marketing. Air conditioned cabs, hillside models, grain loss monitors and automatic controls are all available and ever-larger machines keep appearing. Farmers have, quite justifiably, bought this expensive equipment and have become reasonably proficient operators, capable of maintaining them and, with help from the dealer network, able to repair them relatively quickly when they break down. Even so, in less-than-ideal conditions many different kinds of problem arise and in unfavourable weather combining simply has to stop. Farmers have in general reacted to the combine's sensitivity to crop moisture content by tending to buy 'spare capacity' so as to be in a stronger position in the event of a difficult harvest.

Although combines are universally used and there are taxation considerations which seem to encourage a degree of over-mechanisation, it appears that there are farmers who are not entirely happy about the way cereal harvesting technology has developed. To a large extent the needs of the specialist grain growers are satisfied, although they are likely to take great interest in the newly-introduced rotary combines; they have still to find markets for much of their straw and decide on the most appropriate means of packaging and handling it. Among the ranks of the mixed arable/livestock farmers, however, there are those who would be interested in some other approach. They are often to be found in areas which do not have a reputation for good weather and easy harvests, and increasingly they seem to resent the fact that the baler leaves in the field much of the best (in a nutritional sense) of the non-grain part of the crop.

Once the idea that there may be a need for some alternative to the present combine/baler approach has been accepted a consideration of various possibilities, all of which have some merit, naturally follows. One suggestion that has been made is that the material discharged from the sieving section of the combine could be placed on top of the long straw swath rather than on the ground: it is argued that this would help in the collection of the fine material and would require only minor changes to current machines. Another view is that the combine should be modified so that everything other than the straw walker discharge could be collected and taken indoors for further separation. It is argued that this would minimise grain losses, collect weed seeds and much of the 'fine' material, would simplify the combine and speed up harvesting. Both these suggestions merit investigation, but neither go any way towards meeting the major weakness of the combine — that it is only a 'fair weather' machine.

One of the attractions of whole crop harvesting is undoubtedly that the basic machine is a forage harvester. Such machines are widely used on mixed farms, are mostly trailed and pto-driven and, compared to a combine, they are relatively cheap: they are also not generally being used when cereals are ready to be cut. A direct cut, precision-chop harvester machine was used for most of the work at Nottingham. It is doubtful whether a flail or double-chop machine would be suitable, and early in the work the practice of separate cutting, followed by the harvester fitted with a pick-up attachment, was quickly abandoned because of high field losses of grain. Those who make wilted silage would have to buy an additional cutting attachment, and this would preferably be one having many of the features of a combine table, rather than the fixed-position, fixed-speed reel found on most direct cutting attachments.

Several options are available to deal with the harvested whole crop. The simplest course is to ensile it, and currently this would probably involve the addition of caustic soda: the penalty in this option is that one is left wihh a feed which would not be particularly suitable for dairy cows but would be extremely useful for other ruminants.

A second option would involve, say, a two-way separation producing grain, which may well be treated with an organic acid and later fed to non-ruminants or to dairy cows (for example in conjunction with grass silage), and a 'better-than-straw' material for feeding to other classes of ruminant, presumably after caustic soda treatment and storage. This option would have the appeal of flexibility, relative simplicity and low capital equipment costs. The drawback would be the cost of the chemicals, but the use of the caustic soda would presumably be more than balanced by an enhancement in the straw's feeding value while the grain treatment costs could be minimised by restricting operating times to reasonably fine spells of weather.

The other major possibility is to opt for drying grain which would then make it suitable for sale or, for example, milling. If relatively dry crops were to be harvested then conventional grain drying equipment running on conventional fuel may be the obvious choice. With progressively wetter crops investment in a straw-fired drying system would begin to be justified. If, as may frequently be the case, only part of the straw was required for feeding then three-way separation could be carried out, with only the most appropriate fraction being taken out for caustic soda treatment. The surplus could then be regarded as an inevitable by-product of the system and disposal would involve some small cost. It could therefore be regarded as a no-cost fuel and so probably justify expenditure on a furnace or boiler which may be more expensive than similar capacity equipment designed to operate on oil or gas.

If there are competing demands for straw then complex decisions will have to be made, taking into account such factors as future fuel prices and availability: these would need to be weighed against the value of the nutrients that straw contains and, for example, future beef prices.

To date most of the interest in the work at Nottingham has come from official bodies, individual farmers and farmers' groups. Some has also come from the manufacturing industry but as yet there does not appear to be any further development work in progress, apart from that at Kockums, where the process is seen as essentially one to be carried out on an industrial scale if all the potential benefits are to be gained.

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Economic and practical aspects of high-capacity rotary mower and mower-conditioner systems

C R Tuck, W E Klinner and O D Hale

HIGH-CAPACITY mowing systems can help to reduce the production costs of conserved forages, improve the timeliness of harvesting and ease management problems. A study of unit costs and performance potential of mowers and mower-conditioners point towards moderately dimensioned multiple units arranged around standard tractors as being preferable to extra wide single machines. Basic multi-unit configurations are proposed. Early experience confirms that — as a system — simultaneous tractor front and rear mounting of rotary mowers can be extended to include crop conditioning and partial or complete windrowing.

The high power demand of rotary mowers and mower-conditioners limits the use of wide machine systems to relatively large tractors at present and provides a challenge to improve designs in future.

1 Introduction

Because the digestibility of most forage crops grown for conservation reaches its peak for such a short period and ahead of maximum dry matter yield, the optimum time for cutting is critically brief. A cropping plan aiming for staggered harvest dates and the precise management of available machinery are pre-requisites for good results, given also that weather conditions are suitable. Where large areas of one crop and variety are involved, timeliness is dependent upon a high-capacity mowing system. With the moderately dimensioned machines available in the UK, the choice normally is between mowing at very fast forward speeds with one tractor or using more than one tractor and mower simultaneously. However, sustained high speeds are often impractical, and whilst more than one mower may be justified, the use for mowing of more than one tractor and driver rarely is.

The third choice — extra wide mowers of >3.5 m working width — is not a particularly good option for British farmers. Although swathers and windrowers of such widths can be purchased, they are usually designed for much lighter crop conditions abroad or for other crops like oilseed rape and peas. If used in grasses and legumes, too much crop is placed into the windrows for rapid wilting or field drying, and spreading in a separate operation is often necessary. Moreover, contour following of wide cutterbars on undulating ground conditions is often poor, and transporting the machines between fields can cause considerable problems.

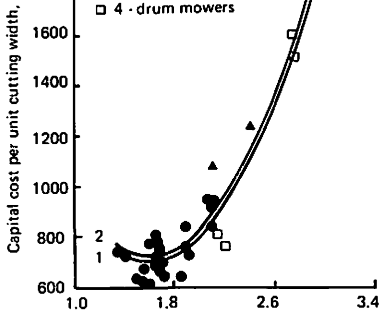
The following is an examination of the likely costs and important practical aspects of attaching more than one mower — or mower-conditioner — to one tractor, to provide a simple and effective high-capacity mowing system. This approach has been made possible by the development of tractor front mounting linkages and drives. Much of the basic data for this study has been taken from the last published commercial survey of relevant information (Anon 1979).

2 Mowers

2.1 Drum mowers

The cutting widths of drum mowers available on the British market range from 1.35 m to 3.0 m, and their capital cost varies respectively between about £1000 and £6000. An indication of the effectiveness of capital expenditure on drum mowers can be obtained by plotting the capital cost t available models per unit width of cut against their nominal cutting width, fig 1. In calculating the best-fit (curve 1), the costs of the two available 3-drum machines have not been considered, since they lie appreciably above the general trend. This is probably so because these machines are manufactured by the company which also makes the most expensive 1.65 m wide 2-drum mower. However, by themselves all three machines fit the trend well.

Fig 1 Capital cost per unit width of drum mowers, March 1979



To avoid undue influence in this analysis of single models from some manufacturers, the same cost/width relationship has been plotted in respect of the mowers made only by the four leading manufacturers, who each supply a comprehensive range of cutting widths — fig 1, (curve 2). Both curves are very similar and show the most cost effective mower widths to be clearly in the 1.60 — 1.70 m range.

From the cost data in fig 1 it becomes clear that above a total width of cut of 2.7 m, ie twice the smallest width, it is possible and substantially cheaper to purchase two identical narrow machines instead of one full-width mower, fig 2. However, to be economical in practice, both narrow mowers would need to be attached to the same tractor. The simplest way of achieving this is by mounting one in front of the tractor and the other at the rear offset to the right in the normal way.

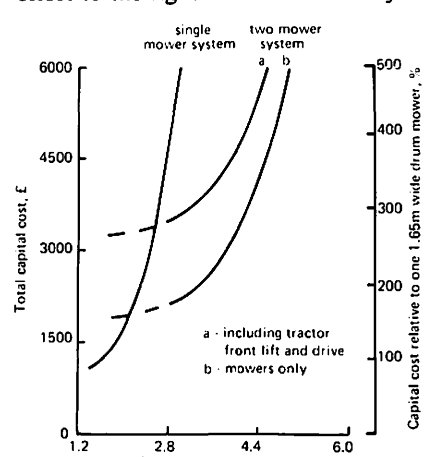


Fig 2 Capital and relative cost of achieving cutting width by one wide or two narrow drum mowers, March 1979

An immediate advantage of front mounting is that the fields can be cut to-and-fro, instead of clockwise round the centre, so that all swaths except the headlands lie oriented in the same direction relative to the prevailing winds. In consequence, drying of the crop stands a good chance of becoming more uniform. It is also relevant that a tractor with front mower and trailing self-loading wagon is exceptionally effective for zero grazing.

The additional capital cost of a commercial front lift linkage and drive, if

C R Tuck, W E Klinner and O D Hale are of Forage Machinery Department, National Institute of Agricultural Engineering, Silsoe.

charged solely to mowing, would add a further £1400 to the two-mower system. Even then this approach is shown to be the more economical above 2.7 m wide. However, a practical point is that, for effective operation, the front-mounted mower has to be slightly wider than the overall tractor track width, ie at least 2.1 m. This makes the minimum nominal cutting width of a two-mower system about 4.2 m. The total capital outlay necessary — including front linkage and drive — compares very favourably with the retail price of the widest (3.0 m) drum mowers on the market. In buying a front mounted mower, there is no cost penalty; of the two machines available in both front and rear mounted form, the front mounted version is cheaper in one case and costs the same in the other. The changes in capital cost with cutting width of single and twin mower systems are also shown in relative terms in fig 2; the base cost which has been assumed is the average for 1.65 m wide 2-drum mowers, currently the most popular size.

If a rear coupling arrangement, as suggested by way of example in fig 3, could be devised for two mowers offset in tandem, double mower systems could then be as narrow as 2.7 m. At that width the capital available for a cost effective coupling unit would be just over £2000, and at a width of 3.0 m it would be nearly £4000.

2.2 Disc mowers

A cost analysis of disc mowers is more difficult, since few manufacturers and only a small range of cutting widths are involved. Fig 4 shows the capital cost per

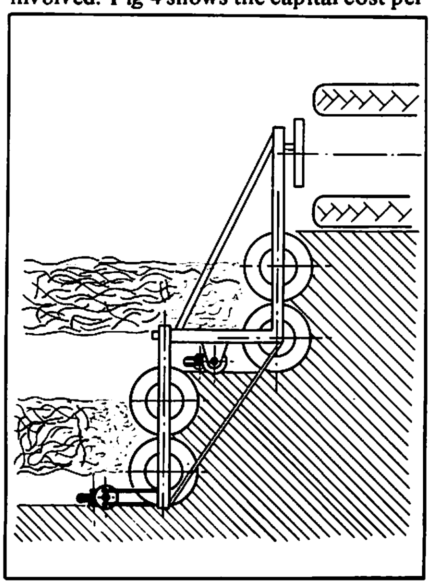


Fig 3 Outline of possible coupling arrangement for two offset drum mowers

unit width, related to nominal cutting width for the few disc mowers on the market. Overall, unit cost is barely affected by width in the 4 to 6 disc range. The available figures show that around 1.6 m the cost per unit width is comparable to that of drum mowers, but at widths of around 2.4 m there is a saving of nearly £350/metre of width in favour of disc mowers.

2.3 The "gang" mower approach

A long-term possibility, needing only straightforward engineering development, is to combine with a front-

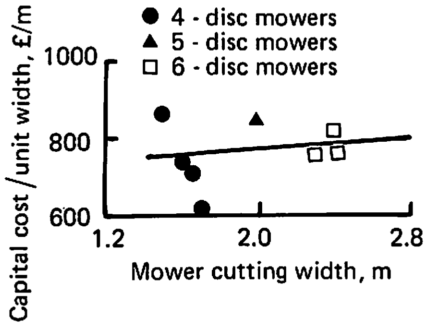


Fig 4 Capital cost per unit width of disc mowers, March 1979

mounted mower a left-handed and a right-handed cutting unit attached to a centrally rear-mounted headstock. Three important potential advantages of such a gang mower system are that the draught forces are symmetrically distributed about the longitudinal tractor axis, close contour following of all cutting units should be easily achievable, and provision for reducing the overall width to within the limits permitted for transport on the highway does not pose undue difficulty. Preferably the lead mower would be of the drum type, so that a swath sufficiently narrow for the tractor wheels to straddle is produced; the rear units could be disc, drum, or hybrid drum with centre disc type mowers. In some cases the capacity of standard tractor front tyres may limit the machines which can be front mounted, but heavy duty tyres should overcome this. Power steering will almost certainly be essential. Semi-mounting of the front and/or rear units is a possibility, should it be necessary.

On the basis of present-day tractor dimensions convenient cutting widths of a 3-section gang mower system are in the region of 6 - 7 m, given that the swaths need to be nominally of equal width. Acceptance of unequal swaths would allow a margin of variation up or down. Other machines like spreading tedders can conceivably be trailed behind the rear units, with the drive being taken from a through-pto.

Although no specific guidance for costing a forage gang mower system is available, on present knowledge it is mechanically the simplest possible arrangement for the overall widths which may be achieved, and therefore it should be more cost effective than any alternatives.

3 Mower conditioners

An attractive, versatile combination is that of a front-mounted mower with a rear-mounted or trailed pick-up conditioner. In effect it is equivalent to a self-propelled mower-conditioner which can be rapidly adapted to performing either function separately, if required. As for other machine combinations which include a front mower, the ideal tractor is one which affords the operator good vision forwards as well as rearwards.

The only trailed conditioner available at present is specifically designed to be matched to a rear-offset mower, so that it treats the previous swath. An in-line arrangement, using the tractor front and rear has been operated experimentally at NIAE; its cost, including tractor front mounting and drive equipment, is likely to be at least 150% of a conventional offset mower-conditioner comparable width. This has to be weighed against the substantial practical advantages which may be gained.

Like the mowers, commercially available mower-conditioners also exhibit an overall upward trend in capital cost per unit width with increasing cutting width, although the scatter is quite large, fig 5. Significantly, drum mower based mower-conditioners of low cutting widths are cheaper per unit width than disc mower based mower-conditioners; however, by the time the cutting width reaches 2.75 m the difference is negligible, probably because of the greater cost contribution of the mower.

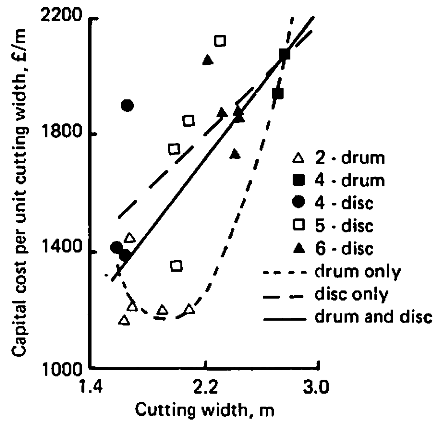
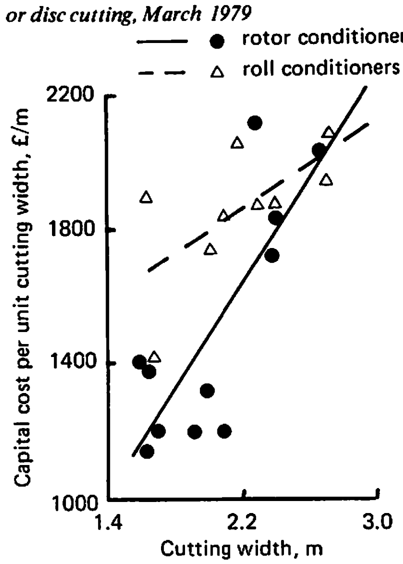


Fig 5 Capital cost per unit width of drum and disc based mower conditioners, March 1979

Two basic types of conditioning are used in combination with drum and disc mowers: treatment by metal spoke or flail rotors and by crushing and/or crimping rollers. In fig 6 the capital cost data are related to the type of conditioning mechanism. It can be seen that rotor conditioners offer considerable cost savings over roller conditioners throughout most of the range, but the

Fig 6 Capital cost per unit width of rotor and roller mower conditioners with drum or disc cutting, March 1979



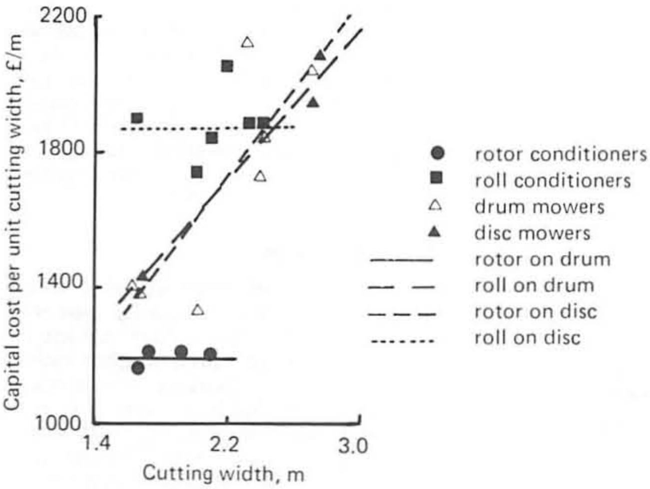


Fig 7 Capital cost per unit width of drum and disc mower based mower-conditioners, March 1979

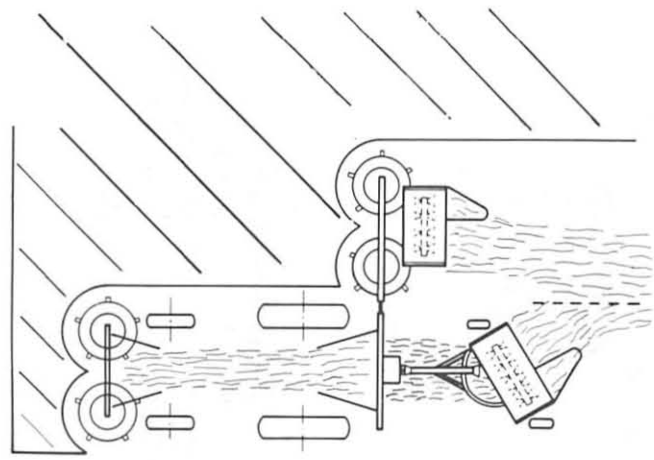


Fig 9 Composite high-capacity system for simultaneous mowing and conditioning

regression lines cross at about 2.75 m. Fig 7 examines the available cost data according to mower and conditioner type. Although the regression lines are not statistically significant, the indications are that (i) drum mowers with rotor conditioners are generally cheaper than with rollers, (ii) drum mowers with rollers are similar in price to disc mowers with rotors, and (iii) disc mowers with rotors are cheaper than disc mowers with rollers up to widths of 2.4 m.

A comparison of the capital cost of achieving wide widths of mowing and conditioning by one single machine or by a dual arrangement can only indicate general trends, because of the variability of the data and the absence of a cost example for a front mounted mower-conditioner. Fig 8 shows the cost relationships in absolute and relative terms for rotor and roller conditioners, based on the lines of best fit in fig 6. Even when taking account of the additional cost of a tractor front linkage and drive, twin unit mowers with rotor conditioners should be economical in theory at the minimum width available of 2 × 1.6 m.

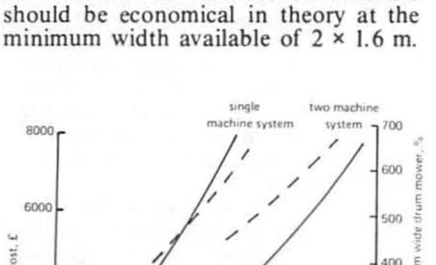


Fig 8 Capital cost of achieving working width by one wide or two narrow mower-conditioners (no allowance for tractor front lift and drive)

However, so far front mounted mower - conditioners are not commercially available. Reasons for this probably include the difficulty of providing attachment points which allow sufficient freedom of movement during lifting and adequate articulation in work at the greater longitudinal offset required, when compared with mowers. A point also needing consideration is the risk of airborne particles emanating from the conditioner unit contaminating the engine cooling systems of conventional tractors. However, none of the difficulties are insurmountable, and if the advantages of a modular mower-conditioner system built around the tractor are accepted, suitable designs could be developed quite quickly. Semi-mounting is one possibility. In the longer term appropriate design changes to tractors would be helpful, to make them more suited to the modular approach.

An interim solution tried successfully at NIAE is shown in principle in fig 9. A front-mounted mower and rear offset mounted mower-conditioner are complemented by a trailed, pto-driven conditioner to treat the front mower swath. Both cutting units are 2.1 m wide and together they give an average working width of 3.8 m. At 8 km/h and a field efficiency of 75% the actual work rate is 2.3 ha/h. The trailed experimental conditioner is so designed that its rotor can be angled relative to the direction of travel (Klinner, W E; Hale, O D, 1980); as a result the treated front mower swath

Fig 10 Immediate windrowing and coupling of windrows achieved with the machine combination shown in Fig 9

can be moved sideways towards, or even on to, the mower-conditioner swath. Without special provision for crop guidance, minimum windrow width is 1.5 m, (fig 10). So far the tractor driver has not found it unduly difficult to operate this outfit, but more sustained work is needed before the ergonomic aspects of the system can be regarded as being satisfactory. Considerable simplification would be possible if efforts to develop a compact front-mounted mower-conditioner should prove successful. Immediate windrowing could then be achieved by appropriately angling the offset rear-mounted unit in relation to the line of travel. On present day tractors it is believed that twin machine systems can be made up to a combined width of 4.5 m.

With suitably powered and equipped tractors it may be possible to arrange a "gang" type mower conditioner system on the lines suggested in fig 11. The central conditioner unit also serves as the mounting frame for the two "wings". Total working widths could be from 6 to over 7 m, depending again on whether or not swaths of unequal width are acceptable. Simultaneous windrowing could be achieved by slanting both offset units backwards at their extremes. Circumstances when this may be appropriate include zero grazing and the cutting of light and short crops for ensiling or high temperature drying. Partial windrowing may have a place occasionally in crops of moderate yield needing only a short wilt. Advantages of immediate windrowing are that production costs and dry matter losses can be reduced, and fewer heavy objects capable of causing damage to forage are swept up. A disadvantage is that the actual cutting width is reduced when the cutting units are angled.

4 Power requirement

On many farms a practical limit to the use of wide mower and mower-conditioner systems is their present power requirement. Table 1 gives the mean figures quoted by manufacturers of power demand per metre of working width for the various types of commercial machine. From cutting research done at NIAE the minimum stated power requirement of 15.7 kW/m for drum

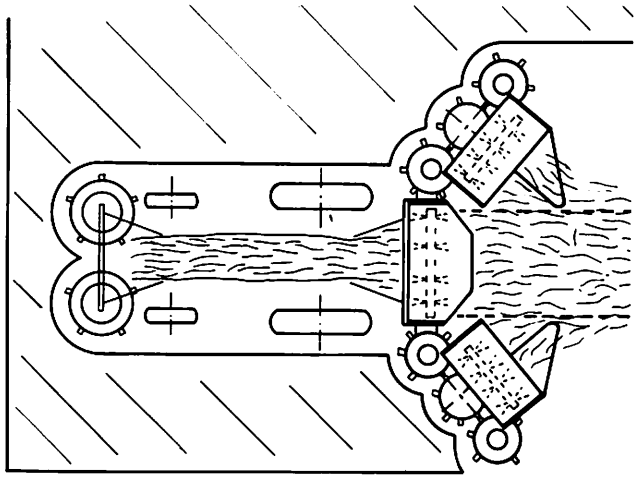


Fig 11 Proposal for a tractor based "gang" mower-conditioner system

mowers is consistent with such a mower working with slightly worn blades in a

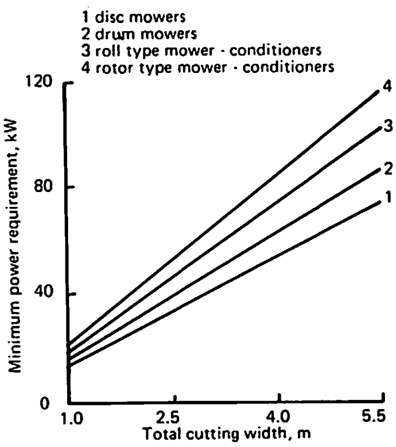


Fig 12 Minimum power requirement for various mowers with increasing cutting width — mean of manufacturers data

crop of about 30 tonne/ha fresh weight yield at a forward speed of around 10 km/h. Disc mowers appear to require about 14%,or 2.15 kW/m, less than drum mowers, and conditioning on average adds 36% or 5.4 kW/m. However, for conditioning by rotors with discrete elements the increase is 45% on average, as against 27%, for roller conditioning.

Using the figures from table 1, a relationship between machine power requirement and cutting width can be calculated for the different machines, fig 12.

If the power available at the tractor pto is limited, examples of corresponding maximum working widths are as shown in table 2.

For gangs of three units of 6.0 m total working width the total power demands would be as follows:

The figures show the greatest scope for improvement to lie in reducing the power demand of both types of rotary mower. Current research at NIAE into the impact cutting process has that objective, and it is also expected that a new generation of brush type conditioners under development will be less energy demanding than the present rotor conditioners (Klinner, W E; Hale, O D, 1980). First indications are that the power saving with brushes over steel spoke rotors can amount to 25 to 40%.

5 Conclusions

The scaling up of drum and disc type rotary mowers and composite mower-conditioners, to achieve high capacity, inevitably leads to heavy, mechanically complex and expensive machines. Among the probable reasons for the disproportionate increases in cost with working width above about 2.2 m are the need for (i) greater structural and drive line strength, (ii) drive line protection against high start-up torque and overloads, (iii) increased strength and complexity in the suspension, and (iv) provision of chassis, drawbar, wheels, etc when the maximum width for tractor mounting is exceeded.

The alternative approach of fitting simple adapted production units in multiples around the tractor could be more than a substitute for wide machines; it has the potential not only of being more economical, but also of solving many practical problems and making possible advanced procedures like unidirectional swath laying and immediate partial or complete windrowing. The call from large farmers, contractors and drier operators for more robusrt and durable primary conservation machinery of high capacity can probably be met more simply and cheaply by strengthening existing machines of moderate size and using them in multiples, rather than developing new outsize equipmnet. The appeal of strong, modestly proportioned mowers and mower-conditioners may prove to be considerably greater than manufacturers anticipate.

The attraction of composite machine arrangements would be further enhanced if endeavours to develop compact mower-conditioners for easy front attachment become successful and the power demand of rotary mowers and conditioning rotors can be reduced by a significant margin.

For some of the possible modular systems to be applicable in practice, the larger wheel tractors on the British market need to be adaptable to driven front mounted machines. Tractor design improvements, to ensure good vision fore and aft, and provision of appropriate external services and operator controls, would help the ergonomic aspects of the systems. Wider availability of reverse drive facilities would greatly increase the scope for new design solutions in the forage conservation context generally.

Table 1 Manufacturers' figures for power requirement per metre of working width

Type of machine	*No of machines in sample*	*Mean of all quoted figures, usually minimum power,*	
		kW	*hp*
drum mowers	32	15.7	21.0
disc mowers	20	13.5	18.1
drum and disc mower-conditioners	19	20.0	26.8
rotor type mower-conditioners	11	21.1	28.3
roller type mower-conditioners	8	18.5	24.8

Table 2 Effect of available tractor power on working width

Maximum power at pto, kW (hp)	*60 (80)*	*75 (100)*	*100 (134)*
maximum working width, m:			
disc mower	4.4	5.5	7.3
drum mower	3.8	4.7	6.3
roll type mower-conditioner	3.1	4.0	5.2
rotor type mower-conditioner	2.8	3.5	4.7

Table 3 Power requirement of 6 m wide 3-unit systems, kW (hp)

front drum and 2-disc mowers	86 (115)
all drum mowers	94 (126)
mixed rotary mowers with roll conditioners	110 (147)
mixed rotary mowers with rotor conditioners	127 (170)

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Use of electrical energy on the farm and prospects for energy saving

P Wakeford

ENERGY saving is an 'in' phrase, and most people when considering the subject tend to think of 'electricity saving' as a good thing in itself. This paper is an attempt to encourage a perspective view of the situation, and to advocate 'the wise use of resources' and 'the sensible use of electrical energy' as providing a more balanced approach than mere energy saving.

Nevertheless, it is obviously in the farmer's interest to seek for ways of saving energy when it can be shown to be economic to do so, and the paper also suggests applications where this may be worthwhile.

Almost every farmer in the United Kingdom is aware of his dependence on electricity for most of the static mechanical jobs done around the farmstead. Whether he is a dairy farmer, pig, poultry, calf or even beef producer, or grows grain or other crops, at some stage in the production of milk, meat, eggs or crops on the farm itself, electricity is virtually essential, and as such is taken for granted.

Motive power

What, however, is not always accepted is that for motive power, electrical drives are the most efficient. This applies to their use for milking, milk cooling, fan ventilation of livestock houses, mechanical handling or crop conservation.

Where farmers choose to use non-electrical drives, the reasons are not necessarily economic, but may often be associated with difficulty in obtaining an adequate supply of electricity for the purpose in mind. Where economic reasons dictate the use of an ic engine for grain or hay drying for example, it is usually because reinforcement of supply appears to be too expensive.

In fact, the charges made for supply reinforcement are a good example of wise use of resources. A new 100 kVA 3-phase transformer with ancillary equipment would involve an Electricity Board in annual costs in perpetuity of at least £200, whether or not a single unit of electricity is used by the farmer. So that in making a basic charge for the provision of this service the Board is merely acting as a good husbandman of resources.

But some farmers, even though they don't like paying for reinforcement of supplies, are increasingly turning to electricity for large drives to replace ic engine drives because they fear increasing difficulty in obtaining oil. Is this making a virtue out of necessity?

Taking a long term view — fortunately from the farmer's point of view, the answer to that question is 'Yes'! The basic reason for this affirmative is that about 73% of all electricity generated comes from power stations burning coal, and the known recoverable coal reserves in the UK are sufficient for at least the next 300 years! With the prospect of restrictions in the supply and increasing difficulty in getting oil over the next 30 years, it makes sense to use electricity for motive power.

Still on the motive power theme coupled with the wise use of resources, what applications can be identified on the farm, over which the farmer can have some confidence in the sensible use of the mains electricity?

I suggest there are at least three, and each involves better use of another resource which electricity helps to ensure. They are:—

- a Barn hay drying in which electric fans help to maintain productivity of grass, and as a result help pay for the fans.
- b Feed preparation on the livestock farm in which electrically driven equipment on the farm itself materially reduces transport costs of cereals between farm and compound mill, and shows savings to the farmer which will pay for the equipment usually in under two years.
- c Control of fan powered ventilation, which when used in a discriminating manner, can help to ensure better use of either or both of two resources, namely feed and electricity itself.

Barn hay drying

The digestibility value of an average sample of hay cured in the field is about 58. By using electrically driven fans to dry hay in barns, the average D-value can be improved to 65. What this means in typical recommended allowances for a dairy cow yielding 13 litres of milk daily and for a bullock gaining 0.9kg live weight per day is shown in table 1.

The gross saving can be set against the cost of hay drying equipment. As an example, consider a 100 tonne centre-duct hay drier supporting 60 Friesian milkers or 60 bullocks, in the installation of which electricity main reinforcement costs of £2000 are incurred (this will not be the general situation but is chosen to illustrate the economic case). Table 2 sets out the economic benefit for both cases.

The installation of a 100 tonne barn hay drier can be seen as making sensible use of electricity by improving herd productivity from the conservation of good quality in grass by drying, and thus reducing the cost of and need to use expensive concentrates.

Feed preparation on the farm

This is another enterprise in which the sensible use of electricity for driving mills and mixers can show substantial savings for the farmer. A report in 1978 by the Price Commission on the compound feeding stuffs industry[1] pointed out (para 3.6) that including payment of all capital and running costs of feed preparation equipment and allowing also for higher working capital to finance his materials purchases, the farmer's net savings could lie between £7 and £13 tonne. Today the *gross* 'value added' by the compounder in

Table 1 Typical recommended allowances for dairy cows and bullocks

	Dairy cow yielding 13 litres/day		*Bullock gaining 0.9 kg/day*	
	Field cured hay	*Barn dried hay*	*Field cured hay*	*Barn dried hay*
D-Value	58	65	58	65
Ration as fed kg hay	8.2	8.2	6.0	8.5
Weight kg of compound	5.6	4.4	2.7	-
and protein level (%)	(14)	(10)	(12)	-
Concentrate cost/day	69p	51p	31p	-
Gross daily saving		18p		31p

P Wakeford is Section Head, Farm Electric Centre.

Based on a paper given at East Anglian Branch Annual Conference 15 November 1979 by P Wakeford and J Gibson of Eastern Electricity Board.

Table 2 Economic benefit of a 100 tonne centre duct drier

Used to support	*60 Milkers*	*60 Bullocks*
	£	£
Capital cost (in an existing barn)	2100	2100
Reinforcement of electricity supply	2000	2000
Total capital cost	4100	4100
Annual costs (estimated useful life ten years)		
Average annual capital and interest payments (on a 5 year loan at 15%)	579	579
Cost of electricity @ 3.5p/kWh	630	630
Maintenance	30	30
Annual cost	1239	1239
Gross saving – (60 x 18p x 200)	2160	
(60 x 31p x 200)		3720
Less annual cost	1239	1239
Average net saving annually	921	2581
Repayment period – years	4.5	1.6

a tonne of feed is probably between £18 and £25.

One typical example of a farm system would involve a capital cost today for equipment of about £11,100 and would be capable of producing 1000 tonnes of feed a year for 15,000 layers and 1250 baconers. It would cost the farmer about £5.60 a tonne to run including repayment of capital and interest, maintenance and running cost, and working capital to finance feedstock purchases. This would thus show a nett annual saving compared with bought in compounds which would cover his capital cost in under a year.

Fan ventilation of livestock houses

Powered ventilation makes intensive production of pigs or poultry a practical proposition. Electronic controls are used nowadays to vary fan speeds with the object of maintaining the constant temperature best suited to optimum production from the stock. In practice the reduction of fan speed, especially in winter, enables metabolic heat from the animals to maintain a temperature inside livestock houses which should ensure that feed they consume is not wasted in maintaining body temperature, but is effectively used to put on liveweight gain or optimise egg output.

Unfortunately there is clear evidence that lower than optimum temperatures are often held in winter, with the result that feed bills increase. While some of this is under the farmer's control, part of whose husbandry should include keeping a daily watch on the actual house temperatures maintained, the work of Michael Barrett at the ADAS unit at Stoneleigh, has shown that some control systems do not in practice reduce fan speeds to the ten percent of maximum which is usually required to ensure maintenance of optimum temperatures.

He has, in fact, quantified this in the case of a typical pig fattening house and fig 1 'Cost effects of reduction in optimum house temperature in a piggery' enables the 'cost penalty' to be assessed[2].

The upper diagram shows, for a typical pig house, the effect of different ventilation rates on the temperature rises which will occur with a given pig population. The diagonal lines show the temperatures which will occur inside the house for a range of different ventilation rates. For example, at full speed of the fans (100%), if the outside temperature is 12°C, the internal house temperature will be 14°C, at which the pig will not be wasting food to keep up its body temperature, ie, the temperature rise inside the house at maximum speed of the fans is 2°C. If a controller is capable of reducing fan speed to ten percent of maximum then at this low ventilation rate the metabolic heat from the pigs will result in a temperature rise of 16°C, and even if the outside temperature falls to -2°C, the optimum temperature of 14°C will still be maintained. However, with a controller which is capable only of reducing fan speed to 40% of maximum then a rise of only 4.5°C will result, and once the outside temperature falls below 9.5°C, the internal house temperature will fall below 14°C. As a result the pigs will use some of the energy in their food to maintain body temperature, will eat more of it and this costs extra money.

The lower diagram enables the cost of this extra food to be assessed. The Institute of Animal Physiology, Babraham, has produced figures for the rate at which pigs consume extra food to maintain body temperature in cold conditions; a 60kg pig would consume an extra 18g of feed per day for every 1°C below the 'lower critical temperature' of 14°C (ref 3). In other words one degree day below 14°C will cost 18g per pig in extra food consumption. For 100 pigs eating feed costing £100 per tonne, this amounts to £0.18 for every degree day below 14°C. With this price data, a 'cost penalty' scale can be put parallel to the degree day scales shown in the lower diagram. (These are for Aberdeen, Yorkshire and East Anglia).

In practical terms, this means that a fan capable only of speed reduction to 40% of its maximum will, even when making allowance for the heat from the pigs, lead to about 850 degree days below 14°C in East Anglia. This will cost the farmer about £155 per year in extra food consumed by each 100 pigs when feed cost is £100 per tonne.

It therefore makes economic sense, for the farmer who contemplates installing fans for controlling livestock conditions, to do three things:

a *Consult a specialist* who understands the characteristics of the system that is to be ventilated, and who knows what the minimum ventilation, as well as the maximum, requirements are.

b *Make sure* that any supplier who offers to sell him fans can tell him how much air will be delivered (in

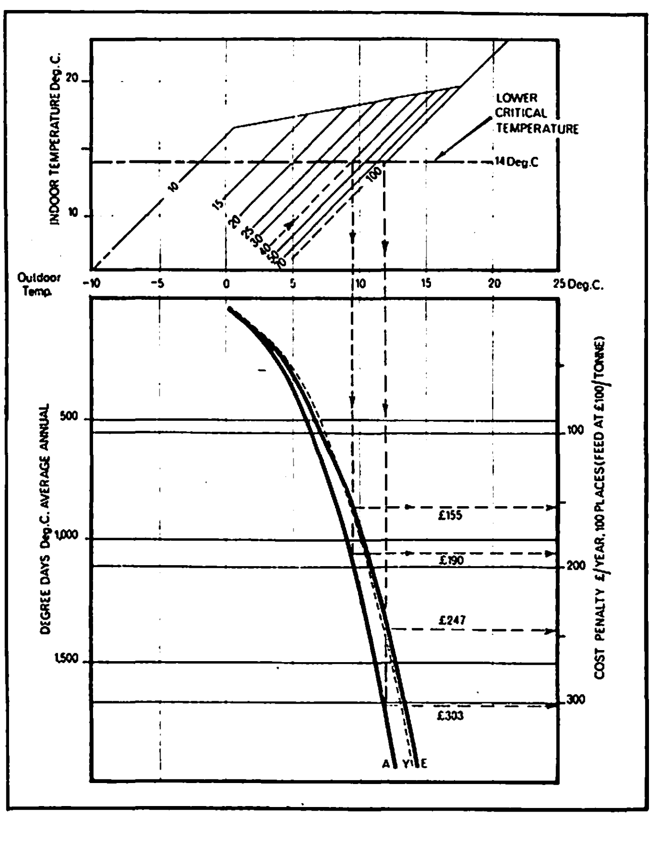

Fig 1 Cost effects of reduction in optimum house temperature in a piggery

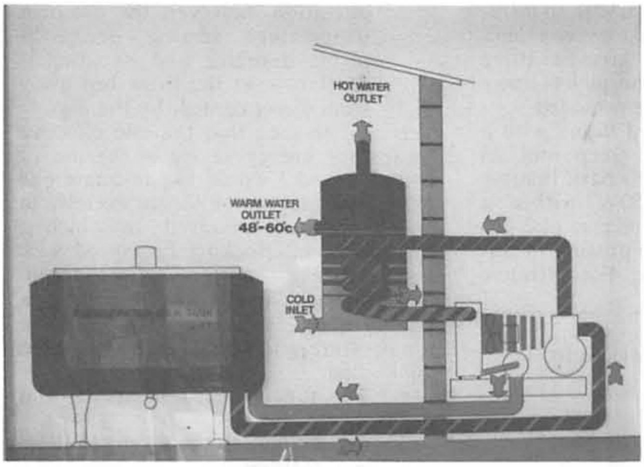

Fig 2 Diagram of heat recovery unit

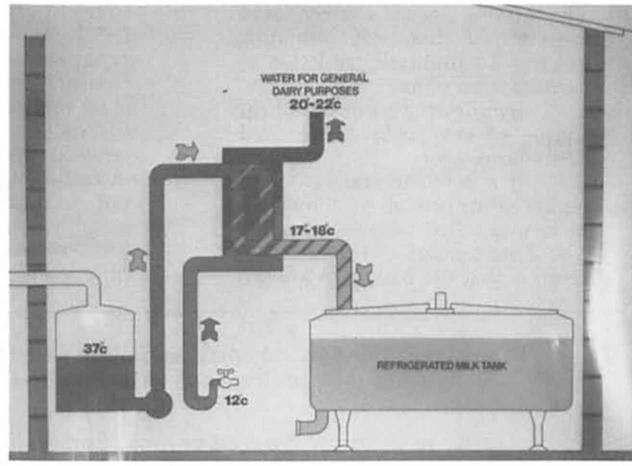

Fig 3 Diagram of pre-cooling system applied to chilled water bulk milk vat

m^3/s or ft^3/min) and what pressure in Pa or inches water gauge can be developed, and this information should be given in writing.

c Enquire whether the controls used can be *guaranteed* to reduce to the minimum speed, *and*, if given, *ask for the guarantee in writing.*

In this way farmers can go a long way to ensure that electricity used for livestock ventilation is indeed a wise use of resources.

Energy saving

At the present time I see two applications where an attempt to reduce the amount of electricity used may be of use to the farmer, and concurrently be a better use of energy than the substitution of an alternative fuel. These are:

a Methods of reducing cost of electricity associated with bulk milk cooling and,

b The use of electrically heated and thermostatically controlled pig creeps.

Reduction of milk cooling costs

Now that bulk milk collection is universal, there is a case for considering ways of reducing electricity consumption of condensing units used for cooling milk in bulk vats. It is by no means certain, however, that the costs associated with devices for reducing electricity consumption for milk cooling are economically viable. In the first place, trials carried out at the NAC Dairy unit over a year (ref 4) showed that electricity consumption for cooling 405,675 litres (89,237 gallons) of milk produced in a year was 6385 kWh or 15.74 kWh per 100 litres (7.16 kWh per 100 gallons), using an icebank (chilled water) system. Assuming an average price of 3.5p per kWh this amounts to 55p per 1000 litres or 25p per 100 gallons. This cost is less than 0.5% of the current average price per litre (11.5p), so that further savings will have only a marginal effect on production costs, and, of course, will involve a capital cost.

In principle it would be sensible to attempt to use the heat dissipated by the condensing unit to raise the temperature of water to be used for water heating for cleaning purposes, and heat recovery units (HRU) to do this have been widely sold to farmers (fig 2).

A second method is to use mains or well water in a plate-type cooler to pre-cool milk to about 15°-18°C, and allow the bulk vat to cool the remainder. In theory this would allow a smaller condensing unit to be installed but in practice this is unlikely to be worthwhile, and would not necessarily be acceptable to the MMB (fig 3).

A third system is to set up a two-stage in-line cooling system, the first stage being mains or well water, and the second stage glycol, following which the milk, cooled to 4°C, is discharged direct to an insulated vat without further refrigeration (fig 4). One practical disadvantage of this method is that the size of the glycol refrigeration system has to be 2-3 times that of a standard chilled water system, so that the capital cost and services for the unit are high.

ADAS have carried out trials on all three systems and table 3 summarises the main economic benefits and costs of each.

Reduction of heating costs in pig rearing

The two main areas in which heat has been used for rearing baby pigs are localised heating associated with farrowing, and more general space heating where early weaning is practised. I think there is scope for reduction of heating costs in both areas; as an example, recent experience, with which the FEC has been associated, has given a clearer indication of the size of the saving likely to be achievable in localised heating for baby pigs after farrowing.

The range of electricity consumption per piglet reared encountered in practice is very wide indeed, and table 4 summarises our main findings.

The scope for improvement is, therefore, enormous and the choices open to the farmer are complicated because of the variety of pig keeping systems practised. This is not the place in which to analyse these possibilities in detail, but some basic husbandry principles can be clearly established which can lead to reduced energy consumption. With farrowing pigs these are:

a Whatever heating system is provided, an attraction light in the warmed area appears to be essential. This should be not less than 15 watts to be effective in drawing the baby pigs away from the sow in the first 24 hours after birth

b The conventional 300W infra-red bright emitter left on continuously in an open area requires adjustment in height both as the pigs grow and at different seasons. Increasingly this is seen as an unacceptable chore and results in an unacceptably high cost of running. It also fails to take sufficient account of the very different environmental requirements of the piglets and the sow.

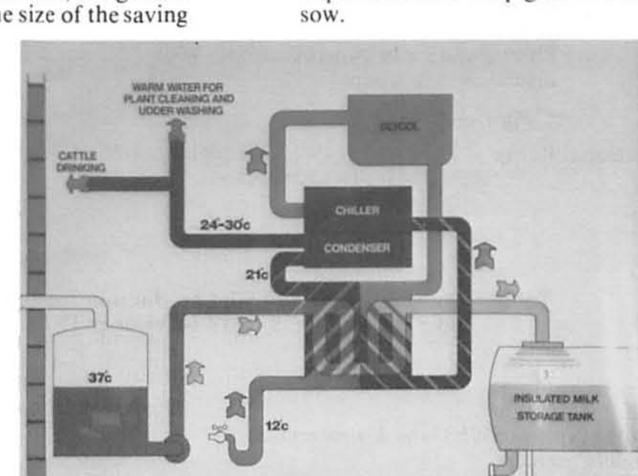

Fig 4 Diagram of two stage in-line cooling (water and glycol) applied to insulated bulk milk vat

c The boxing in of a creep area especially if effectively insulated, can make a dramatic reduction to consumption either

i By allowing a constant heat source of say 100W to be used continuously, or

ii If a conventional heater of higher rating is used, by allowing it to be controlled thermostatically. The disadvantage of the boxed in creep is that the baby pigs are not so readily visible as under an infrared lamp, but it does enable a separate higher temperature environment for the piglets away from the sow to be provided.

d Electrically warmed floors with a covered insulated creep and an attraction light and a basic loading not exceeding 150W within a suitably dimensioned area of 0.7 to 0.9m² offer another possible means of energy savings. For effective operation, however, the use of a temperature sensing device is highly desirable and its siting is crucial — in the floor but away from direct contact by the pigs.

It will be seen that the one effective means for energy saving is the use of controls, and I would like to quote one example from a monitoring exercise in which we were involved, in which a method of interlocking fan speed with voltage to bright emitters was introduced. The method used was to have a thermistor sensing the house temperature, and whenever this exceeded 20°C, first

a The fans reduced in speed, and then

b The voltage to the bright emitters was reduced.

It is not suggested that this form of control or the method of heating is ideal, but we were able to carry out parallel trials over a 9 month period comparing energy costs of this system with an identical house in which the lamps were left on continuously, and fans only were subject to modulating control from a temperature sensor. The results are shown in table 5.

The saving of nearly 25% illustrates the potential for *sensible* energy savings in pig rearing, and there is no doubt in our minds that there is scope for further significant savings if covered creeps are used.

Table 3 Examples of benefits and costs association with three devices for reducing milk cooling costs (ADAS figures)

	Heat recovery unit	*Pre cooling to CW bulk tank*	*2-stage direct cooling to insulated bulk tank*
Suitable for	100 cow herd	100 cow herd	200 cow herd
Typical capital cost	£600 for 275 litre HRU (draw off 140 litres)	£1000 for 1150 litres/h	£10,000 for system with 4500 litre insulated bank (cf two 2300 litre cw tanks cost £8500)
Benefit	Provision of hot water to 55°C	a Electricity cost for cooling reduced by 40% b Possible use of pre-cool warmed water for dairy water heating	45%
Typical cost saving	£170 per year in water heating cost for no increase in milk cooling cost	a £120 per year b £50-60 per year possible	a £310 per year b £180 per year possible
Other conditions	Requires MMB approval	Cost of water may exceed electricity saving. Water storage facilities needed (2 x max daily milk prodn)	Cost of water for 200 cows could be £375 per year. Water storage facilities needed (2½ x max daily milk production)

Table 4 Range of costs per piglet reared with localised electrical heating (annual averages)

		Consumption per piglet reared kWh
1	*Worst case to date* (Farm-Elec Centre monitoring)	26
2	*Great House EHF*	
	a Uncontrolled	21.4
	b Thermostatically controlled uninsulated box creep	10.5
	c Thermostatically controlled insulated box creep	6.7
3	*NAC Pig Unit Room B*	8.2

National Range – 2-26 units (kWh) per piglet reared at 3.5p per unit = 7-91p per piglet reared.

Table 5 Consumption and piglet production for the period 20 February 1978 to 13 November 1978

House number	5	6
Control system	Fans & heaters	Fans only
Consumption kWh (fans & heaters)	14,583	19,320
Piglets reared	1340	1336
kWh/piglet	10.9	14.5

Conclusion

Finally, I would summarise our view of energy saving by saying that we should all, and particularly farmers, be concerned with *conservation of resources* rather than saving of energy alone. Electrical energy is an essential resource, which in spite of recent increases in costs, still forms a small part of production costs, usually well under 5%. But the amount of other resources which farmers have to use, and in particular feed resources, are capable of being significantly reduced by the sensible use of the electrical resource. Of course, there is scope for electrical energy saving, but the right perspective in these matters is to be aware of an overriding need to achieve a knowledge of the wisest use of *all* the energy resources which the farmer has to exploit in the rearing of his animals or the growing of his crops.

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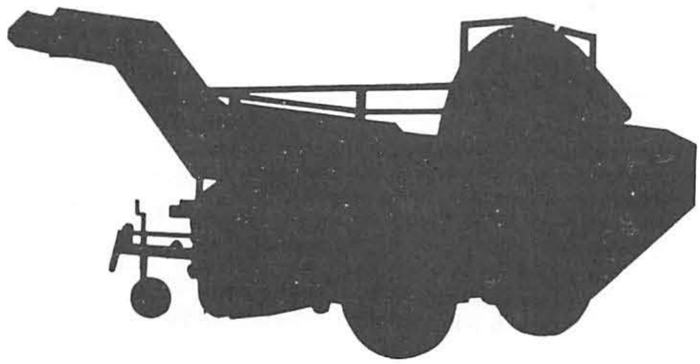

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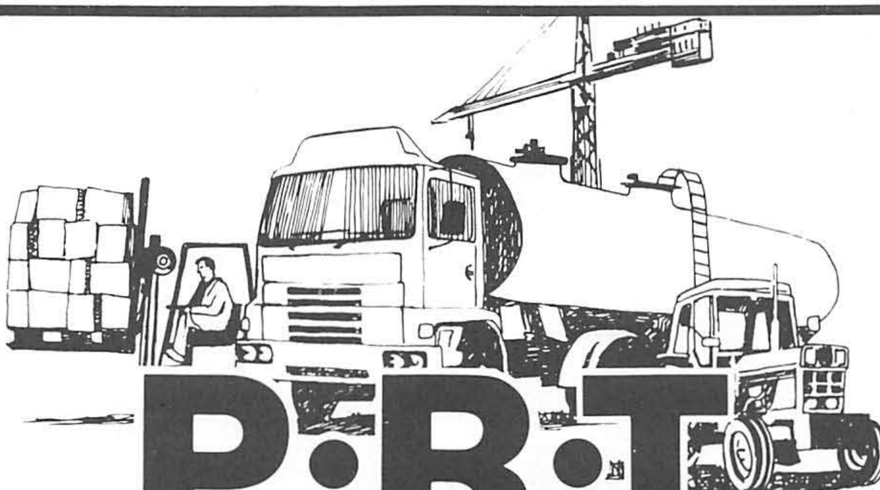

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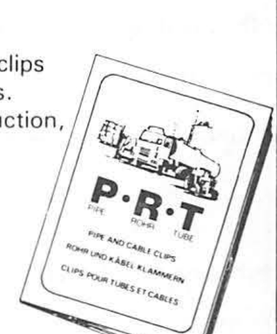

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Institution 1979 meeting award

AFTER consideration of the many excellent papers eligible for the 1979 Meeting Award, the Institution Awards Panel recommended that the Award be made to Mr John Matthews for his paper:— "The Power Requirement for Tillage in the Next Decade", which was presented at the Institution's 1979 Autumn National Conference, and subsequently appeared in Volume 34 No 4 of the Journal.

John Matthews is the Head of Tractor and Cultivator Division at the National Institute of Agricultural Engineering, Silsoe, where he has been on the staff since 1959.

After leaving the Royal Latin School in Buckingham, Mr Matthews was employed in the Research Laboratories of the General Electric Company as a Student Assistant, and read Physics at London University during this period. After graduation, he was promoted to the Scientific Staff at GEC. He left that company to join the National Institute of Agricultural Engineering, where he became quickly involved in the development of a grain moisture meter and grain drier controller which was successfully marketed. He contributed to work on data logging, before becoming involved in the field of automation in agriculture and in ergonomics. It was in the subject of ergonomics that Mr Matthews soon established himself as an expert, producing several papers and finding solutions to a number of important problems. As a result of this work, he is recognised as probably the best informed man in Britain on the subject of ergonomics in agriculture. His subsequent work has been involved with tractor performance and research into implement control and traction.

John Matthews

John was admitted to the Institution of Agricultural Engineers in 1969 in the grade of Fellow. He is also a Member of the Institute of Petroleum, and serves on a number of committees, including some of the British Standards Institution's committees on agricultural engineering topics.

The Award will be made at the Institution's annual luncheon in Coventry on 13 May 1980.

National Conferences - 1980 - 1981

1980 Spring	Electronics in agriculture (Supported by the Institution of Electrical Engineers)	Tuesday 25 March 1980, University of Newcastle. (Northen) Branch).
1980 Annual	Agricultural engineering for the 21st century	Tuesday 13 May 1980, Allesley Hotel Allesley, near Conventry.
1980 Autumn	Agricultural machinery manufacture in developing countries	Tuesday 14 October 1980, National College of Agricultural Engi- eering Silsoe, (South East Midlands Branch).
1981 Spring	Engineering in horticulture	Tuesday 17 March 1981. Wye College, Ashford (London/ Kent Branch).
1981 Annual	Engineering for beef production	Tuesday 12 May 1981. National Agricultural Centre. Stoneleigh.
1981 Autumn	Engineering for Intensive vegetable crop production	Tuesday 13 October 1981, (North Western Branch).

Registration forms will be sent to members as they become available.

Enquiries to:

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