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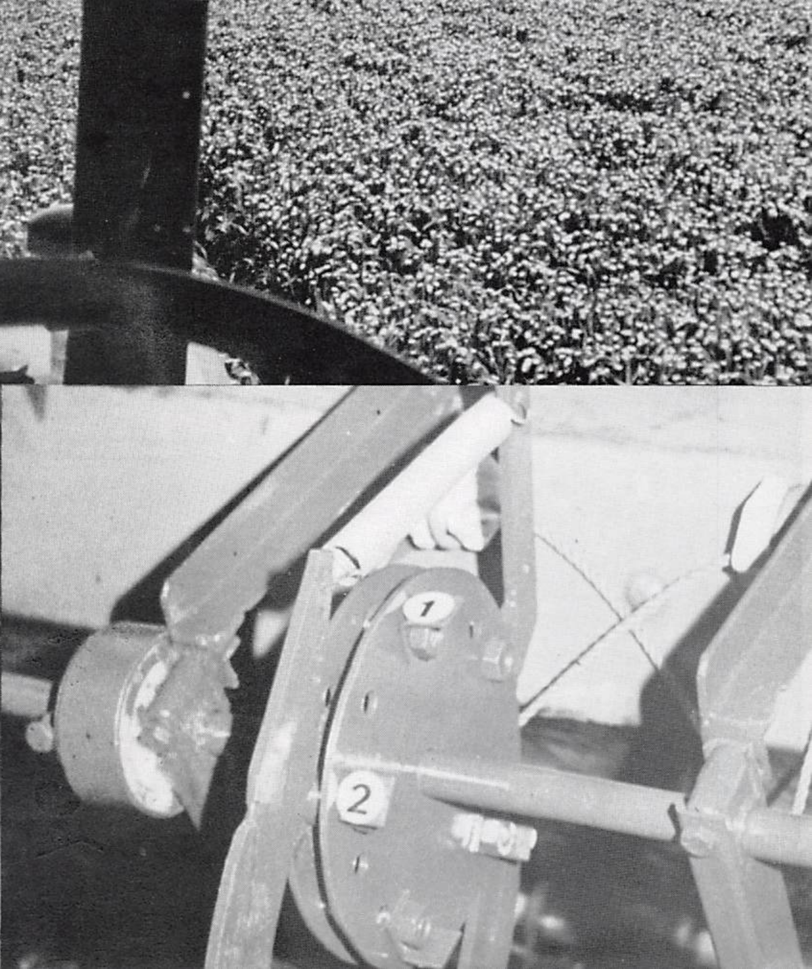

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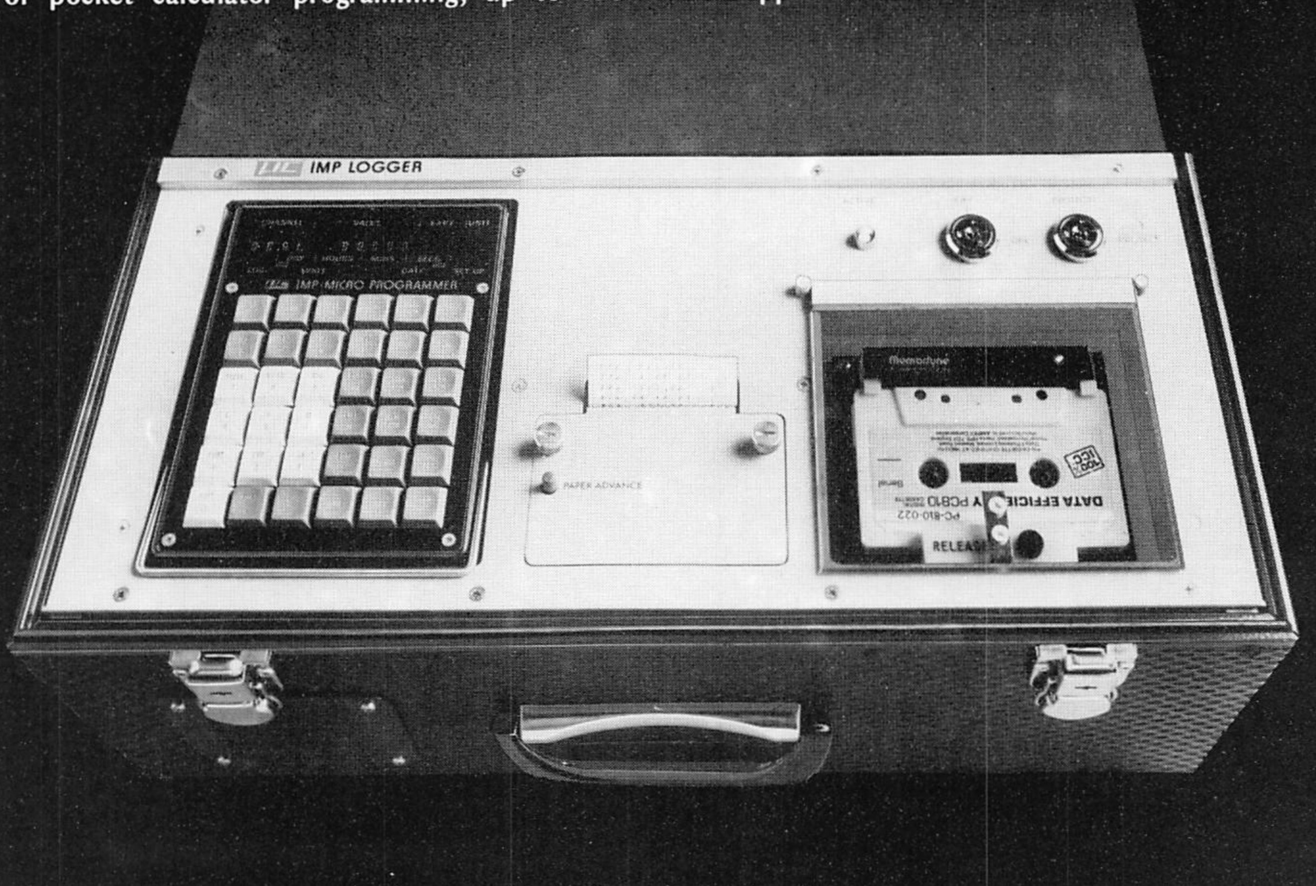

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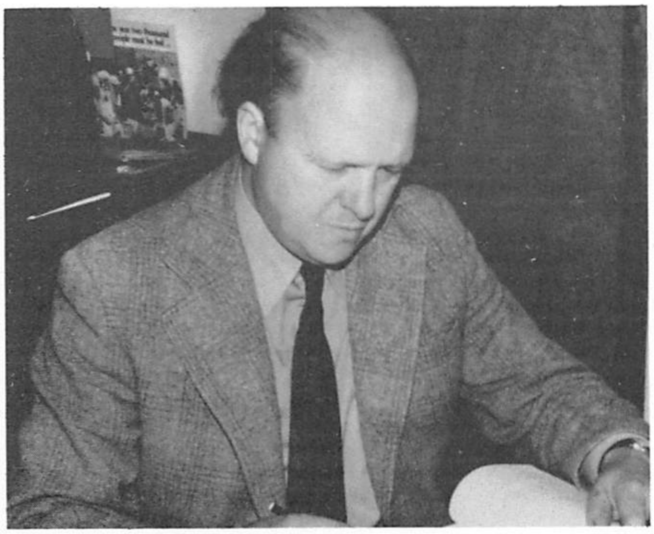
Cover – Top: tramlines in Huntsman wheat; bottom left; pre-emergence marker wheel; bottom right: spool and ratchet, operating cross shaft to cut-off slides.

Efficient use of resources in agricultural engineering

B Wilton



AS man has developed so have his demands on the world's resources, and as a citizen of the world each man in each age feels entitled to his share. The demands and expectations of individuals vary; nomads and forest dwellers have very different levels of expectation from, say, entertainers, businessman and politicians who may have airliners at their disposal; nevertheless all are making some demand on 'the system'.

As the world population increases, as communications improve and man's expectations rise, so the demand on finite resources accelerates. Up to the present time we have been able to find enough new mineral deposits to more-or-less satisfy demand, but it will inevitably be progressively more difficult for following generations who will find that we have spread these materials around the surface of the earth. We do not destroy the elements of their composition; we simply change their form and discard them as our manufactured products break, wear, become obsolete or are contaminated.

As the world population has increased so has the supply of food. Agriculture has responded to the demand; moreover in recent years in the developed world it has done so while at the same time reducing its labour force. The mechanisation of food production has continued apace: agricultural engineering, worldwide, has been a growth industry; agriculture has used more fertilisers, more power, more agrochemicals. In short it has used resources at an increasing rate. Where will it end?

In a mere hundred years we have moved from the steam engine and its gang of men to the driver whose tractor's potential may be measured in terms of hundreds of horse power. We have moved from the few pigs kept in a sty to huge concentrations of animals capable of producing as much effluent as a town. We transport animal feeds half 'way round the world, we air freight out of season perishable vegetables from one continent to another. Inevitably there will continue to be changes in agriculture and in trading patterns, but these may well be for rather different reasons from those which influenced past changes.

There is, for instance, a small but growing body of opinion which is urging a change towards human diets that contain less animal products but more grain and vegetables. There is growing interest in national self-sufficiency, and we are now beginning to hear arguments, some put by responsible agricultural engineers, for a move to employ more people in food production rather than less. One part of this argument is that it is surely better to have people working productively in a rural environment than to have them unemployed in an urban one; another part is that it may become economically sensible to use human skill and effort to replace power and sophisticated equipment in some situations, particularly if the task is a short seasonal one.

In order to focus attention on the need for agricultural engineers to anticipate changes and face up to them, the theme of the Annual Conference was chosen to be 'Efficient use of resources: implications for the agricultural engineer'. We, and the agricultural industry we serve, use such a variety of resources that selection of the most important was not a easy matter. Energy, naturally, came to mind first because, more than any other resource, we have been made aware of the fact that oil, at least, is in short supply. Unlike some other potentialy critical resources, alternative sources of energy can possibly be exploited but not without considerable investment and inconvenience. Dr David White reviewed the topic thoroughly and examined in detail the place that unconventional sources of energy might play.

Our manufacturing industry, in common with others, uses not only energy but also metals, plastics and rubbers: what contribution if any, can designers of farm machinery make to the predicament we are facing? This was the question which John Fox posed and endeavoured to answer in a well-argued paper.

Michael Nicholson and Ingemar Bjurenvall addressed themselves to questions of utilising field machines, static plant, labour, and animal and crop by-products. We all know that under-utilised plant, wasted materials and badly managed labour can be found here in the UK, which is said to have an "efficient agriculture": these speakers outlined techniques and methods of organising their operations which are designed to minimise such sources of waste.

Perhaps the most difficult topic was dealt with by Brian May. He considered the training of professional agricultural engineers, their motivation and the future needs of both the manufacturing industry and the public services. They are the key people who will play a decisive part in shaping the future of the industry, but they need the incentives both of challenge and reward. Professor May, in a thoroughly professional way, left the Conference in no doubt that agricultural engineering is capable of providing both.

B Wilton, convener of the conference, is Lecturer in Farm Mechanisation, University of Nottingham School of Agriculture & Horticulture.

INSTITUTION OF AGRICULTURAL ENGINEERS

1979 Autumn National Conference

Date: **9 October 1979.**

Venue: National Agricultural Centre, Stoneleigh, Kenilworth.

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

This conference is being organised by the Royal Agricultural Society of England in association with the National Executive Committee and the West Midlands Branch of the Institution.

Registration forms were mailed to all UK members on 24 July 1979. If any other person wishes to have further information — with a view to attending — they are invited to contact:—

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

Efficient use of resources : implications for the agricultural engineer

Design considerations for optimum performance and durability

J V Fox

THE oil crisis of 1973 marked the beginning of the end of the "throwaway" philosophy of planned redundancy. By underlining our present total dependence on petroleum it also highlighted the finite nature of most of the other resources we had tended to take for granted. Notable amongst these are iron and steel and whilst known world reserves are equivalent to over 200 years' consumption at present rates, a recent projection suggests that they may be nearing exhaustion much sooner; in fact by 2040.

Table I World reserves of metals (Eyre 1978)

	Quantity 10^9 tonnes	Years to exhaustion (I)	(ii)	(III)
Aluminium	1.2	100	31	55
Chromium	0.8	420	98	154
Cobalt	0.02	110	60	148
Copper	0.3	53	27	57
Gold	0.00001	11	9	29
Iron	100	240	93	173
Lead	0.09	26	21	64
Magnesium	0.8	97	46	94
Mercury	0.0001	13	11	41
Molybdenum	0.005	79	34	65
Nickel	0.07	150	53	96
Tin	0.004	17	15	61
Tungsten	0.001	40	28	72
Zinc	0.12	23	18	50

(I) At constant rate of usage (present)
(II) If demand grows exponentially
(III) As (II) but reserves supposed to be larger by factor 5.

**Eyre SR, The Real Wealth of Nations, E Arnold 1978. Based on US Bureau of Mines, ore economically extractable as of 1968.*

It is further relevant to remember that substantial amounts of energy are required to convert these raw materials into finished products; for example, a recent estimate indicates that agricultural machinery manufacture in the UK accounts for 52 TkJ (10^{15} joules) annually.

Manufacturers, therefore, must move towards a recognition of their responsibility to ensure that their products are engineered for resource efficiency in total terms, from the initial energy and material investment through the useful working life to the final residual value. This philosophy will ultimately demand a change in the accepted commercial approach to design and production, as well as to the selection, purchase and use of machinery, and experience tells us that such a change will only occur to the extent that it is profitable in the terms of the day. It follows from this that irreplaceable resources would need to increase in cost in proportion to their scarcity in order to achieve maximum economy and efficiency of utilisation, and it is hard to see how this can

J V Fox NDA NDAgrE FIAgrE, Managing Director of Bomford and Evershed Ltd.

Paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The Conference Centre, National Agricultural Centre, Stoneleigh, on Tuesday 8 May 1979.

Table II Rough outline of overall energy budget (JCO 1978) for UK agriculture up to the farm gate per annum (TkJ)

Input or energy subsidy		Output or energy available to man			
Solid fuels	4	Cereals	55		
Electricity	33	Potatoes	15	Arable crops	88
Petroleum fuels	84	Sugar beet	18		
Fertilisers	71	Horticulture	4	Horticulture	4
Agrochemicals	1	Beef	20		
Machinery	52	Sheep	5	Livestock	94
Imported feedstuffs	73	Pigs	17		
Solar energy	not accounted	Poultry	12		
		Milk	40		
Total	318		186		186

$$\frac{\text{Output energy}}{\text{Input energy}} = \frac{186}{318} = 0.58$$

Joint Consultative Organisation for Research and Development in Agriculture and Food Report of the Energy Working Party, Report No 1, December 1974.

happen through the action of normal market forces, which tend to reflect current, rather than all-time availability of commodities. One is tempted to think in terms of a new world currency based on resource equivalents or units, instead of the present purely notional or gold-based standards; a system which would at least provide an opportunity for realistic relative values to be established.

However, the present objectives are more limited in the sense that we are seeking means whereby we can maximise our efficiency in the use of resources within existing financial constraints, and this paper sets out to examine the opportunities and problems which are likely to present themselves at the various stages in the development of a typical agricultural machine, from initial conception to the finalisation of the design for production.

Determination of requirements

The point at which a product begins is with the definition of the need for a machine to carry out a particular task, but before going forward from that point it is wise to go back still further and consider the task itself in some detail. Is it necessary, and if so have the requirements been clearly defined? In very many cases traditional methods have been mechanised without regard for their contemporary relevance and it is therefore not sufficient to assume that a task is necessary, nor that its effects are understood, simply because it has been performed in a certain way for many years. It may have been made redundant, or the requirements may have been changed by recent developments, or indeed it may never have been necessary. Hence a broad review, covering related fields, is desirable to confirm that the proposed development is aligned with current needs. This review may indicate a requirement for basic research to determine actual requirements, for example the optimum seed-bed conditions for a particular crop or the method of handling or harvesting to minimise damage and loss, and such research may reveal opportunities for a new and better approach which should not be overlooked.

Optimum means of achievement

The task having now been defined it is necessary to consider the various ways in which it could be carried out, and this stage should be undertaken without preconceived ideas, as far as possible. It is much easier to copy existing competitive designs than to originate a fresh approach, but if there appears to be a possibility of improving on what has gone before the various options should be studied from all angles. Nowhere in the whole design process is lateral thinking of more importance than at this stage; there is invariably more than one way of doing anything and it may well be that substantial energy savings can be achieved by tackling a problem from a different angle. A good example of this is to be found in a design for a cotton stalk puller produced by the Overseas Department of the NIAE and developed by Agri-Projects International Limited. The requirement was to mechanise the extraction of the cotton stalks and roots for subsequent collection and burning as a disease control measure, and early attempts involved passing a horizontal cutting blade below the roots. This process involved a high power consumption, very low workrate and undesirable soil disturbance, whereas the final solution provides pairs of contra-rotating pneumatic-tyred driven wheels which grip and extract the stalks from four rows simultaneously, achieving a work-rate some eight to ten times that of the undercutting process, and an energy consumption per unit of useful work done of about eight per cent of that required in undercutting.

This contrast between one method of working and another is probably exceptional, but even a ten per cent energy saving across the board in UK agriculture, which should be relatively easily attainable, would reduce oil consumption by some 1.5 million tons over a ten-year period. It is, therefore, well worth taking the trouble to maximise the performance of new designs before putting them into production, both in relation to the energy investment that the product represents, and to its operating costs. In every case the comparison must be in terms of useful work done, with the emphasis on "useful" as defined by the careful initial study of the actual requirements of the task to be performed.

Within this general area of performance, the question of optimum size, row or working width, power consumption and work-rate must be taken into account. The present trend towards ever-increasing size and power of tractors is likely to continue in the short-term, but these large power units are appreciably less energy-efficient than more conventional tractors. This is mainly because it is very difficult to fully load a large tractor for more than a small proportion of its time, and also relates to the high-resource investment represented by the tractor itself and by the heavy machinery which it needs if its potential is to be realised. Ideally therefore the aim should be to provide 60-70% load for a medium tractor (70-90 hp) at a working speed related to the nature of the task. However, it is not the responsibility of the manufacturer to decide what is good for the customer; any serious commercial organisation can only operate on the basis of supplying what the customer wants, and if he wants to work uneconomically and is prepared to pay for it then the prodcut range must take this into account.

Technical specification

The concept having been finalised it is necessary to draw up a full technical specification for the product, but this in turn depends upon a definite and conscious decision as to the design or service lift of the product. Here the designer is faced with a somewhat intractable problem since it is necessary to allow for potentially very wide variations. At one end of the scale there is the small farmer who may use a particular machine for no more than say three or four weeks in a year and at the other is the contractor who may operate it on a full industrial basis for fifty weeks with overtime or even shift working. In addition the export markets present special difficulties due, for instance, to the not uncommon combination of relatively unskilled labour and extreme conditions. If a realistic life for a machine is taken to be ten years the actual utilisation may theoretically range from 10 x 4 x 30 hours; ie 1200 hours, to 10 x 50 x 45 hours; a total of 22,500 hours. Quite obviously that is an unbridgable variation and it would be entirely reasonable in the case of almost all mobile agricultural machines to assume an upper limit of working life of the order of 12,000 hours. Even that, however, is ten times greater than the minimum usage, and if one adds back the effect of the spectrum of working conditions the disparity is once again increased.

Factors affecting service life obviously vary depending upon the type of machine which is being considered. For instance, a highly seasonal machine is subject to less variation than one which can be used throughout the year; a harvester and loader/backhoe are representative of these categories. However, the basic design features which determine service life can be identified and are considered below in terms of the characteristics of materials, quality and replaceability of wearing parts, design of structures, overload protection devices and parameters for testing.

From the commercial standpoint a clear appreciation of design life is very important, since a product that is over-engineered will be too costly to compete in the marketplace whilst one that is too light in construction will quickly acquire a reputation for unreliability. In practice today far too many products succeed in falling into both of these categories, the very antithesis of efficient use of resources. Massive steel sections with almost infinite useful life combine with relatively flimsy working parts and non-replaceable wearing surfaces to create a product that is at the same time expensive and unreliable. Still worse, at the end of its useful life the machine is dumped in a hedge or a corner, too good to throw away but not good enough to use. Thus large quantities of irreplaceable resources are squandered annually throughout not only this country but the world, and this must indeed be a grim prospect for the longer term interests of our society, since agricultural machinery manufacturers are by no means unique in this respect.

Ideally, when drawing up the technical specification for a product, the aim should be to ensure that the major components will have a working life as nearly as possible equal to the design life of the whole product, and that parts which are subjected to wear can be economically replaced at intervals throughout that life, thus providing the opportunity for full and complete utilisation of the original investment. This is by no means a simple matter, particularly where considerations of safety are involved, and it must be accepted that where an eventual structural failure could represent a safety hazard the parts in question will be designed to last indefinitely; even so there is a significant difference between a component so designed and an arbitrarily chosen steel section which may be excessively and wastefully understressed.

In fact, this concept provides the key to the solution of the conundrum of how to reconcile the enormous variations in utilisation which can occur. Provided that the basic structure is of adequate strength and durability to last almost indefinitely it is then only necessary to provide in the design for ease of maintenance and convenient replacement of parts such as bearings, bushes, pins, seals, drive components and other parts subjected to wear and tear. If this concept were followed by manufacturers as a general rule there would undoubtedly be significant increases in first cost of many machines but the long-term dividends in terms of resource utilisation and customer satisfaction would be substantial.

Design parameters

Turning now to the design itself the primary requirement must be for ease of operation to ensure that optimum work-rates can be achieved with minimal stress on both the operator and the machine. Controls must be conveniently positioned as must the working parts which the operator needs to keep under observation, and all possible steps must be taken to minimise both noise and vibration. Noise is a major factor in operator fatigue, whilst vibration is undoubtedly the major enemy of any machine with reciprocating or rotating parts. Vibration-induced fatigue can make nonsense of the most painstaking design calculations and in its more extreme forms is capable of producing cracks in sheetmetal work within hours and structural failures in a matter of days, as well as constant loosening of thread components. It is desirable to design rotating parts with inherent dynamic balance, wherever possible, and thus to confine the addition of balance weights to the correction of minor imbalance due to manufacturing tolerances.

Following closely behind ease of operation is convenience and cost of maintenance, and coupled with this is the design of wearing parts to ensure maximum utilisation of the costly materials involved. We are all familiar with, for example, cultivator points or plough shares which may still have 80% of their original mass when they are worn out and have to be scrapped. By careful design this ratio can be reduced substantially, with significant savings in both cash and resources. An important development in this area may arise out of work on ceramic-tipped soil engaging parts at NIAE; if it proves possible to replace the tip only, after a substantially greater life than that of an equivalent Ni-Hard or steel part, this would indeed represent a breakthrough in technology. A more traditional approach is of course the application of hard-weld to wearing surfaces and this technique, too, has an important place in terms of the conservation of resources, although its application is limited to use in conjunction with steel wearing parts.

The careful choice of materials is crucial to the success of a design, and in the case of wearing parts there is an inevitable compromise between abrasion and impact resistance. Clearly the greater the hardness the better will be the wearing qualities, but the penalty comes in the corresponding reduction in tensile strength; psychologically a user will react more strongly against an apparently unworn component which breaks than against one which wears out, but remains intact, even though both may have worked the same number of hours, cost the same and be equally useless at that point in time. Either of these situations may be the result of an incorrect choice of material, or of incorrect heat treatments, or of unsuitable design, and this is an area which fully justifies detailed attention during development, backed up by constant monitoring in production to ensure that standards are maintained.

Testing and estimation of stresses

Test procedures are critical in this respect, and the establishment of realistic and appropriate standards is a prerequisite. There is no substitute for field experience, but once this has been gained there is a very positive advantage in comparative rig testing. Not only are the results repeatable but comparisons can be rapidly made between different materials and configurations, and the tooling can be subsequently utilised for quality control purposes. This principal applies equally to the testing of structures, where modified or redesigned components can be tested against those which have been previously proved in the field. However, in every case the rig test must be based on a datum of practical field experience if the results which it produces are to be valid and of practical value, and it must be so designed as to reproduce stresses of the orientation and magnitude experienced in both normal and extreme operating conditions.

How strong should it be?

One of the principal problems in the design of agricultural machines is that actual working stresses are very difficult to quantify. This is partly due to the extreme variability of working conditions, and partly a result of the fact that users invariably try to tackle work for which the machine was not designed. Examples are legion; some which come readily to mind include the use of a subsoiler adjacent to large trees to cut the laterial roots which had been bending plough beams, a subsoiler used to break up a wartime airfield concrete runway, a cultivator scarifying a hardcore farm road prior to regarding, an hydraulic flail hedgecutter operating as a stump grinder and regularly mulching six-inch diameter trees, not to mention stone walls. The effects of accidental, and sometimes deliberate, overload can be mitigated in many cases by the provision of safety devices such as spring-loaded toggle mechanisms, hydraulic relief valve systems or shear bolts, and where such systems can be employed they confer a major benefit on the designer, as well as on the user. From the designer's point of view it means that the maximum stress which can be imposed on the structure should be limited by the safety device, and hence he is able to work within known parameters. The result is likely to be a more economical design, with improved performance and fewer failures in service. Unfortunately there are always areas which cannot be so protected, and here the starting point can only be an informed guess. In such circumstances it is important to ensure that the prototype is built sufficiently weak to make initial failures a virtual certainty; the structures concerned can then be progressively strengthened in the knowledge that cost is not being incurred unnecessarily, and the designer will obtain quite precise data on the working stresses actually generated.

Safety aspects

No review of the design considerations for optimum performance and durability would be complete without reference to the vital importance of safety. Quite apart from the untold pain and human suffering which result from accidental injury, accidents themselves exact an appalling toll in terms of resource wastage, loss of production and financial cost. No saving or economy at any stage of design or production which could in any way be prejudicial to safety can ever be justified, since the cost of just one accident will outweigh any savings which might have been made. The designer must therefore regard the provision of built-in safe operation as a central feature of his brief, and must concentrate upon achieving it without compromising the performance of the product. A machine which works better with the safety guards removed is a badly designed machine, and a potentially dangerous one, since human nature being what is is, once the operator finds this out he will leave the guards off.

On the same theme, the indirect contribution to safety and performance of comprehensive, well-written instruction manuals is immense, and their provision must be regarded as being of equal importance to any other major and indispensable component of the product. This is often a special problem for the smaller manufacturer, who cannot justify the employment of specialised staff to meet an intermittent demand, and it may well be desirable in these circumstances for him to call on the services of independent specialists, who can undertake such work on a contract basis.

Engineering for resource efficiency in total terms, therefore, implies a total dedication to a philosophy which begins by probing and questioning the relevance and validity of the task itself, explores the possible means by which the task, when defined, can be carried out, selects the optimum solution, and then requires a design combining the highest possible efficiency comptabile with minimum expenditure of energy and materials. It is a challenge which we must meet if future generations are to find their share of Earth's resources waiting for them when they arrive.

Douglas Bomford Third Memorial Lecture

(in association with the South East Midlands Branch of the Institution)

Date: 17 October 1979 at 17 30 h.

Venue: National College of Agricultural Engineering, Silsoe, Bedford.

Subject: "Analysis of Economic Success in Agricultural Engineering".

Speaker: Dr F E Jones, President of the Engineering Industries Association.

Dr Jones will present an analysis of the economic performance of a number of (anonymous) manufacturers based upon data which have been published by the companies concerned. The progress of these British organisations will be compared with a small sample from Japan, Europe and USA.

Efficient use of energy in agriculture and horticulture

DJ White

Synopsis

THIS paper considers UK energy prospects in relation to reserves and consumption, the effect of increases in energy prices on crop production costs, and the responses of agriculture and horticulture in terms of conservation measures and uses of new sources of energy that are already being made and some other, more speculative ones, that might come about.

UK fossil fuel reserves could last for 150 years at present rates of consumption. But energy prices must be expected to rise in real terms and this will affect crop production costs. It is shown that conservation measures may be practised in relation to existing energy sources in respect of powered machines, cultivations, drying of crops and glasshouse heating. Alternative sources of energy are considered including solar energy, crop residues, animal wastes, windpower, industrial waste heat, and geothermal energy, and some examples are given of their application to agricultural systems. Some of these measures appear to offer prospects of more efficient use of energy but they must be economically viable if they are to be adopted. Thus, their future will be critically dependent on the availability and cost of energy from more conventional sources.

1 Introduction

Any rational discussion of energy in relation to agriculture and horticulture requires an examination and understanding of the future prospects of energy supplies, of their probable cost, and of the effect of cost increases on the price of agricultural produce. Availability of energy and its cost are the principal factors which will determine any strategic measures that are taken to change existing practices or to use alternative energy sources.

Thus in considering the possibility of more efficient use of one of our most vital resources, energy, the following subjects are discussed in this paper:

(i) UK energy reserves and consumption;
(ii) the effect of increases in energy prices on crop production costs;
(iii) the current responses of the industry to the energy situation in terms of conservation measures and the use of new sources of energy, together with some more speculative views on possible further developments.

2 UK energy reserves and consumption

The UK's present situation is one of overwhelming dependence on fossil fuels; for example in 1977, 95.8% of our energy[1] was provided by coal, petroleum and natural gas (table 1). The UK's indigenous sources of energy with estimates of recoverable reserves[2] and life based on the consumption in 1977[1] are shown in table 2. Coal is by far our largest reserve and could last for over three centuries. Since both gas and oil may be synthesised from coal, or replaced by coal, it is convenient to put all fossil fuels together and it is then seen that these could meet our total energy requirements for a century and a half.

Table 1 Primary energy consumed in the UK 1977

Resource	Consumption in original units	Energy equivalent PJ	Percentage of total energy
Coal	123 Mt	3,150	34.0
Petroleum*	90.5 Mt	4,080	44.0
Natural gas	1.57 T ft^3	1,660	17.8
Nuclear electricity	40,000 GWh	350	3.7
Hydro-electricity	3,920 Gwh	50	0.5
Total	–	9,290	100.0

*Includes 10.2 Mt used for non-energy purposes.

Table 2 Estimates of the UK's indigenous energy resources

Resource	Estimated recoverable reserves: Unit given	Estimated recoverable reserves: Coal equivalent Gt	Consumption in 1977 Gt of coal equivalent	Estimated life (reserves/consumption
Coal	45Gt	45	0.123	366
Oil	3-4.5 Gt	5-7.5	0.154	32-49
Natural gas	50-60 T ft^3	2-2.4	0.063	32-38
All fossil fuels	–	52-55	0.340	153-162
Uranium	–	40	–	–

Much depends, however, on the energy growth rate that is assumed. Over the 20 years to the energy crisis in 1973, primary energy consumption in the UK grew at an average rate of two per cent per annum[2]. In 1973, the Organisation of Petroleum Exporting Countries (OPEC) quadrupled oil prices and this caused a reduction in demand; but this has now recovered and is once again close to the 1973 level[2]. Significantly, oil prices are now no longer out of line with the general level of inflation, and if we were to return to the pre-1973 energy growth rate of two per cent for the long term, indigenous fossil fuels would be exhausted in about 70 years.

The UK has no indigenous uranium resources but the amount of this material already here could be equivalent to some 40 Gt of coal if the plutonium formed as a by-product in thermal reactors using uranium is recycled through fast breeder reactors[2]. Although the world has large uranium reserves, the nuclear power industry is still in its infancy and there are problems relâting to the environment and public acceptability to be overcome before the role that nuclear power will play can be reliably assessed[2].

In summary it may be said that compared with most other industrialised countries, the UK is well-placed in respect of indigenous energy supplies. In the early 1980's, we will have sufficient indigenous resources to balance our total energy needs, but production of North Seal oil and gas is likely to decline before the end of the century. We will again become dependent on imported oil and gas and scarcity will undoubtedly justify a premium price for these commodities as world resources become depleted. The use of these natural hydrocarbons may become restricted to premium application such as chemical feed-stocks and motor fuels and, as they decline, coal will assume great importance as a supplementary sources. The Department of Energy suggests[2] that the average level for energy prices must be expected to rise, perhaps doubling by the year 2000 in real terms. This will reflect the increased resouces which will have to put into producing energy as supplies get scarcer and more capital intensive sources are developed.

3 Energy used in agriculture and food production

To feed the population of the UK involves an expenditure of about 16% of the nation's total energy use (table 3); this covers the many

Table 3 Primary energy involved in food production, UK 1973

	Primary energy PJ	Percentage of national consumption (9260 PJ)
Agriculture (to the farm gate)	361	3.9
Processing, packaging, distribution	648	7.0
Food storage and preparation	449	4.9
Total	1458	15.8

D J White PhD CEng FIMechE FIAgrE, Ministry of Agriculture, Fisheries and Food.

Paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The Conference Centre, National Agricultural Centre, Stoneleigh. on Tuesday 8 May 1979.

activities that take place before food reaches the plate[3,4]. It will be noted that in making unprocessed food available at the farm gate agriculture uses only four per cent of national energy, one-quarter of the total, with the remainder being used in processing, packaging, distribution, food preparation and storage. With this four per cent of national energy, we grow a little more than one-half of our food[5,6].

A more detailed breakdown of energy use in agriculture[7,8] is shown in table 4 and it can be seen that the largest use is petroleum (23.6%), followed by fertilisers (23.1%), machinery (14.4%), off-farm feedstuff processing (14.2%) and electricity (9.2%).

Table 4 Primary energy consumed in UK agriculture, 1973

Item	PJ	per cent
Solid fuel	4.1	1.1
Petroleum	85.0	23.6
Electricity	33.1	9.2
Fertiliser	83.5	23.1
Machinery	52.0	14.4
Feedstuff processing (off-farm)	51.3	14.2
Chemicals	8.5	2.4
Buildings	22.8	6.3
Transport, services	16.3	4.5
Miscellaneous	4.3	1.2
	360.9	100.0

There is little doubt that this energy use is absolutely vital to UK agriculture and that present levels of production are highly dependent on it. The benefits may be illustrated by the fact that as recently as in the two decades from 1950 to 1970 energy use in the form of direct fuels and electricity increased by a factor of 1.7 while the labour force was halved. During the same period, increased energy inputs in the form of fertilisers helped to produce increased yields of arable crops, with a corresponding increase in output ot metabolisable energy, in some cases by factors of four or five times the amount of energy put in through fertilisers[7,8]. In effect, we have substituted energy for manpower through the increased use of machines, and we have substituted energy for land though the use of increased fertilisation of crops. We have released resources such as men and land for other purposes at the expense of our resources of energy.

The nation's food supply is so vital that it seems reasonable to suppose that agriculture's energy demand would be given high priority in the event of an energy shortage. But agriculture would no doubt be expected to become a more efficient user of energy, and it certainly cannot expect to be insulated from the effect of rising prices.

It is not an easy matter to assess quantitatively how a rise in the price of energy will affect the cost of producing a given commodity. A breakdown of costs has been studied for a number of arable crops and direct fuel and oil costs were found to be in the range six to eight per cent, so doubling oil prices would raise production costs by as much due to this cause alone. However, energy is also used in the production of fertilisers (which account for 15 to 20% of crop production costs), machines and buildings and the effect of this must also be considered. One of the most energy intensive inputs is that of fertiliser and it has been estimated that doubling in energy prices would lead to about a 15% rise in the cost of fertiliser production. If this is so, then this would cause a further rise in production costs of about three per cent. The other items are not readily assessable; the author would hazard a guess that doubling energy costs would raise production costs by perhaps ten per cent, but certainly not more than 20%. Thus, because direct energy inputs to the arable crops are relatively low, the effect of a substantial price rise is not immediately catastrophic. The same conclusion is not valid for heated protected crops, such as early tomatoes, where direct fuel costs have been as much as 40% of total production costs[9].

In the case of animal products, direct fuel and oil inputs form only a small percentage of production costs and so there is a lesser direct effect of energy price increases. However, in the case of pigs, poultry meat and eggs, where feedingstuffs amount to 70 to 75% of total costs, and to a lesser extent in milk production where they amount to over 40% of costs, cost increases could largely reflect increases in costs of production of a crop such as barley, and they might well again be of the order of ten to 20%.

In these examples, a doubling in energy prices has been assumed, but of course the actual change may prove to be more than this by the end of the century. While it has been shown that this would not raise costs dramatically, the situation is still one of great uncertainty and there is every reason to consider measures that may be taken to achieve greater energy efficiency and to ameliorate the effects of predicted rises in energy prices.

4 Energy conservation

4.1 Direct use of petroleum fuels

Almost one quarter of the energy used in agriculture is in the form of petroleum fuels; the breakdown[7] in table 5 shows that one-half of this is used by tractors and self-powered machines, and one-quarter in glasshouse heating. Consideration will now be given to some of the conservation measures that may be taken at present or which may be economic at some time in the future.

Table 5 Use of petroleum fuels in agriculture, UK 1972/73 (May to June)

Sector	Consumption Kt	Energy equivalent PJ	Energy per cent
Tractors and self-powered machines	925	42.1	48.5
Vehicles, lorries, vans, cars	293	13.7	15.8
Glasshouse heating	496	21.8	25.2
Heating, drying, lighting	198	9.1	10.5
Total	1912	86.7	100.0

4.2 Operation and maintenance of tractors and machines

It is perhaps almost too obvious to say that the efficient use of energy depends on maintenance of machines (especially cleaning of injectors and air cleaners[10]), the knowledge and skill to drive them economically and the correct setting and maintenance of implements. Regular servicing may also provide an indirect saving of energy by reducing the demand for spares and new machinery. Attention to implement maintenance is important because worn shares, tines, knives, and other cutting elements can increase the energy needed to carry out the work as, of course, can poor lubrication and adjustment.

It is worthwhile using the smallest tractor available which is capable of doing the job required. Matthews[10,11] has compared the fuel economy of two pairs of tractors on a light job each pair being a high and a low powered model from each of two manufacturers (table 6). The larger tractor in each case required 20 to 25% more fuel than the smaller adding probably three to four per cent to the cost of doing the work. With a smaller tractor, rolling resistance of the wheels is minimised, the engine may operate at a greater proportion of maxmimum power and at optimum efficiency if a gear is selected which will allow the engine to operate near to its maximum torque. The tractor should be ballasted and loaded so that wheel slip does not exceed 15 to 20%, at which point traction efficiency is normally a maximum.

Matthews has also shown that selection of a machine in the first instance can be of importance (table 7) because the specific fuel consumption of tractor engines of nominally the same power output can show a difference of as much as 15% between one manufacturer and another; this leads to a two per cent difference in

Table 6 Comparisons of the fuel consumptions of smaller and larger models of tractor ranges when employed for a lower power (11.5 kW or 15 hp) task

Tractor	Max. engine power kW (hp)	Engine power needed for 11.5 kW (15 hp) drawbar power	Specific fuel consumption at engine operating condition kg/kWh	Fuel consumed per hour kg
Manufacturer A, smaller	35.6 (47.4)	16.6 (22)	0.233	3.86
Manufactuer A, larger	56.0 (74.1)	19.0 (25.2)	0.247	4.69
Manufacturer B, smaller	37.8 (50.0)	18.0 (23.9)	0.261	4.70
Manufacturer B, larger	66.3 (87.7)	19.5 (25.8)	0.306	5.97

Table 7 Some typical specific fuel consumptions (grammes per kilo-watt hour at maximum pto power) from OECO test reports

Manufacturer	A	B	C	D	E
Individual models	183 176 184 184	197 185 185 183	209 209 208 203	219 221 213 202	229 198
Mean	182	187.5	207	214	214

overall operating costs. The difference is doubtless related to certain features of engine design; however machines can also have different transmission efficiencies so that even for the same power developed at the engine, there can be significant differences in the power developed at the wheels or power take-off.

4.3 Cultivations

In recent years there has been a move towards minimising cultivation operations because of the several advantages that it offers when practised under trouble-free conditions. These can include decreased manpower requirements, saving of time at a critical period, reduction in soil damage due to the passage of heavy machines and a saving in fuel used. Reduced cultivation usually means replacing conventional ploughing and its accompanying secondary cultivations by shallow ploughing (10 cm deep), chisel ploughing or rotary cultivation, all with or without secondary cultivations which may in some cases be carried out at the same time as the primary cultivation. Where soil conditions allow it, seed may be directly drilled into the ground without prior cultivation. Experiments have shown that this requires only one-teneth of the fuel used by a conventional cultivation system involving ploughing followed by a spring-tine cultivator[12]. Impressive though this is, we need to look at it in its proper context, that is, in relation to the total energy inputs required for cereals production; in table 8 it can be seen that fertilisers account for as much as one-half of the primary energy used and substantial amounts are also used in manufacturing machines and drying grain[3]. The overall effect is that the direct drilling system uses only about 11% less energy than the conventional one.

Table 8 Energy budgets for winter wheat, primary energy MJ/ha year

Item	Conventional system		Direct drilling system	
	MJ/ha year	%	MJ/ha year	%
Nitrogen	7430		7430	
Phosphate	665		665	
Potash	322		322	
Fertiliser sub-total	8417	47.9	8417	53.9
Seed	782	4.4	695	4.5
Herbicides	139	0.8	278	1.8
Tractor fuel, cultivations	1846		212	
Combine harvester fuel	625		625	
Fuel sub-total	2471	14.1	837	5.4
Cultivation equipment	701		627	
Tractor	489		166	
Combine harvester	1590		1590	
Drying plant	550		550	
Machinery sub-total	3330	19.0	2933	18.8
Grain drying	2436	13.8	2436	15,6
Total	17575	100.0	15596	100.0

4.4 Crop drying

Where artificial drying of crops is practised, this can be a considerable user of energy in relation to field operations that crops require. In the UK climate, cereals are frequently harvested at a moisture content in the range of 18 to 22% and this must be reduced to nearer 15% for storage. Bailey[13] shows that all-electric in-store type of drier may use twice as much primary energy to dry a given quantity of grain as do the electrically-fanned oil-fired driers of the continuous or in-store types.

In grass conservation, minimum energy is used if natural drying methods are employed to make hay or if grass is made into silage. In contrast high temperature drying of green crops is a highly energy intensive process. Manufacturers of driers have reacted to rising oil prices by introducing modifications to plant which can save considerable amounts of energy and, at the same time, increase throughput. There are various schemes and arrangements[14-19] but the main aim is to recover as much as possible of the considerable amount of heat that is exhausted from the drier drum in the mixture of air and water vapour. This is achieved in a number of ways; by recycling part of the exhaust to the drier inlet, by using it to pre-dry the fresh crop, to blanch or heat the fresh crop or to evaporate juice which has been squeezed from the fresh crop in a mechanical press. Savings vary from 10 per cent for simple exhaust recycling up to 40% for some of the more complex schemes. Where removal of moisture by squeezing is used, the throughput of the dryer may be doubled because of the reduced amount of water to be evaporated. These developments are extremely interesting but the plant modifications are expensive and the question is whether the costs can be recovered in a reasonable pay-back period.

4.5 Glasshouse heating

Glasshouse heating accounts for 25% of the petroleum fuel used in agriculture and horticulture and is undoubtedly the sector which has been hardest hit by rising fuel prices, simply because heating forms such a large proportion of the cost of producing protected crops; for example, fuel and power accounted for 40% of the production costs for early tomatoes in 1975[9].

In many houses, there is scope for energy economies through improved installation, operation and control of heating equipment. To minimise spatial temperature gradients, steel heating pipes should be installed at low level around the perimeter walls, rather than overhead. With warm air systems, air should be distributed through perforated film plastics ducting near to the ground. Control sensors should be carefully positioned since they can be subject to errors from radiation and draughts unless they are correctly screened and aspirated. The highest rates of heat loss occur in strong winds; shelter belts, consisting of trees, hedges or woven or extruded plastics netting, can reduce heat losses.

It has been shown that the heat loss from a glasshouse can be reduced by placing a canopy between the crop and the glass at night. This reduces the heat transferred by water vapour condensing on the inner surface of the glass and it also reduces radiation loss from the crop. Measurements on a commercial nursery[20] showed that use of the canopy throughout the year would result in an annual fuel saving of about 20%.

Another development is an inflated roof greenhouse which has both heat and light saving features. The design reduces the supporting framework to stanchions and gutters only and it uses an air-supported roof consisting of a double layer of plastics film (secured to the edges of adjacent gutters), the two layers being held apart by a low inflation pressure. By eliminating the opaque supporting structure, light transmission is comparable with that of commercial glasshouses and a heat saving of up to 45% is possible[21]. This design is now being developed commercially and an 0.1 ha block is under construction at Lee Valley Experimental Horticultural Station.

4.6 Heat recovery from bulk milk cooling

Milk is taken from the cow at about 35°C and is cooled to about 4°C as quickly as possible to maintain keeping quality. During refrigerated cooling, heat is normally rejected to the atmosphere; however this heat can be utilised to heat water in a storage tank. In a refrigeration unit, the highest temperature heat is available after the refrigerant has been compressed and it is normally rejected to the atmosphere through an air-cooled condenser. In the commercial heat recovery units now available, a refrigerant-to-water heat exchanger is either interposed between the discharge side of the compressor and the air cooled condenser or replaces the condensing unit completely.

From the work done at the National Institute for Research in Dairying[22], and based on an installation for 60 cows with an 1100 litre tank, it is suggested that the heat taken from the milk is sufficient to heat 130 litres of water to 43 to 60°C twice daily. The approximate installation cost is about £250 and could save a farmer about £70 per annum.

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5 Alternative energy sources

5.1 Solar water heating

The simplest direct solar energy collector is a flat plate type in which radiation passes through a transparent cover plate and is absorbed on the collector panel. Heat is transmitted to a fluid, usually water, flowing in passages in the panel or over the surface of the panel. The cover plate reduces convection losses and also acts as a radiation rectifier, because it is transparent to incoming radiation but opaque to the infra-red radiation emitted by the collector. Typically, 50% of the incident energy may be collected at 55°C for British summer conditions[23]. The use of solar energy for domestic heating purposes is well established but must be seen as a means of fuel saving rather than a complete replacement for traditional methods.

It is not surprising that some agricultural and horticultural applications of solar heating are also being pursued. At Auburn University, USA, a poultry house is heated by solar energy[24], the heat being collected by copper plate solar water collectors and the warm water stored in insulated steel tanks. In Virginia, USA, solar water heaters are being used in conjunction with a heat pump in a scheme to provide environmental control in a piggery nursery building[25].

In New Zealand, a solar water heater system has been built and installed at a commercially operated dairy farm milking 350 cows[26] where the daily requirement is for 250 litre of water at 97°C and 500 litre at 60°C. The system is a once-through design, that is, throughout the day the water passes once only through the solar panels and then into hot water cylinders where it is stored until it is used. The solar panels are mounted on a frame outside the milking parlour, at an angle of 40° to the horizontal, and face due north. Over a nine month period the system collected nearly 30% of the total energy used to heat the water to the required temperatures. Although it was concluded that the system was barely economic, the author pointed out that the tariff for electricity used for water heating on New Zealand farms is unrealistically low. In considering solar energy for our own use, it should be appreciated that the New Zealand climate is more favourable than our own in that the average daily insolation during the course of the experiment was 15MJ/m^2 whereas here a value of about 10 MJ/m^2 would have been expected.

5.2 Application of solar heating to crop drying

Solar energy is extensively used in crop drying and experiments are in progress which seek to enhance solar energy capture to reduce the supplementary fossil fuel inputs that are so often necessary. Crop drying systems invariably use air as the heat and mass transfer medium and the basic design of solar air heaters is similar to the flat plate water collector. However, the low volumetric specific heat and low heat transfer coefficients of air compared with water necessitates the use of large collectors and ducts if worthwhile amounts of energy are to be obtained.

One of the simplest systems is that installed in Wisconsin, USA, which uses as a collector part of the galvanised roof of a metal building[27]. A false ceiling was installed under the roof over one-third of the building to give a solar collector of 140 m^2; air was drawn through this chamber and blown through a grain bin 8.2 m diameter and 5.5 m high. During 1974 about 50% of the required supplementary heat for drying was obtained from the collector, and in 1975 the solar contribution was increased to 93% the increase being mainly due to the effects of weathering of the galvanised roof and to improved management of the system. After two years of use, 58% of the cost of the materials for collecting solar heat had been recovered in the form of savings in fuel costs.

In Sweden, work on solar heat collection is being carried out at the Agricultural College at Lund, and in the south of the country a 600 m^2 collector has been built into the roof of a hay barn[28]. The south-facing aluminium roof has been covered with a layer of black laminated glass-fibre. Above this is a clear glass-fibre sheet fixed to give a 30 cm wide gap. The sun heats up the black layer and five fans suck air through the opening at the ridge and across the heated layer at a rate of 150 m^3/h. The warmed air is then drawn down the side of the building, via a channel made by a false wall, and blown up through the barn floor and the hay.

At the Scottish Institute of Agricultural Engineering work on the performance of simple solar collectors has been carried out in conjunction with measurements of insolation data to provide the basic information needed to design solar attachment areas for both bin and floor storage of grain. For a substantial contribution to be made by solar energy, the collector area per unit mass of grain will need to be large; nevertheless the Institute hopes to make provision to incorporate solar heating in a grain store which is to be built. Bare plate collectors have also been constructed as an integral part of the grain drying bin itself and they take the form of a secondary wall which encircles the bin to form an air space between it and the bin wall. In the bin constructed by Morrison and Shove[29] in Illinois, USA, the secondary metal wall extended around two-thirds of the circumference of the 5.5 m diameter bin and the air space was approximately 8 cm wide. When the outside of the collector surface was painted black, it was found that the collector efficiency was approximately 30%. The authors' experiments led them to suggest that the investment in the collector could be recovered in three to six years from the savings made in fuel costs for drying.

Finally, a collector based on a black-painted absorber surface covered with a translucent, fibre-glass reinforced plastic material, was evaluated in South Dakota, USA[30]. This enabled grain to be dried to about 13% with an apparent saving in energy of 26%.

5.3 Energy crops

The photosynthetic process converts solar energy into fixed energy in the form of carbohydrates and cellulostic material which may then be converted into hydrocarbon fuels by fermentation, pyrolysis or hydrogenation. There is little likelihood that crops will be grown specifically for energy purposes in the UK because yields of dry matter are only about 20 t/ha; this means that to produce the energy equivalent of our present oil consumption would require an area of about 25 Mha, an area which is some 6 Mha greater than the area of the UK[4]. To produce even 10% of our present oil consumption would require a cropping area equivalent to one-eighth of the UK.

Despite this, it has been argued that there is a considerable area of marginal land which is not suitable for agriculture and this could be used for raising energy crops, particularly by means of afforestation[31]. In energy plantations trees would be closely spaced and harvested by copppicing to allow new growth to develop from the old stems. In Ireland, a range of tree species have been planted on a number of sites on different soils to investigate short term yields (up to five years)[32]. It has also been suggested that fuel crops might be sandwiched between food crops in the rotation and Jerusalem artichokes, fodder radish and mustard were mentioned as possibilities[33] for the UK.

If the use of land to raise crops for energy is practicable anywhere, it is most likely to be in the tropics where dry matter yields can reach 85 t/ha. Cassava and sugar cane are being considered as energy crops in Brazil, and a more exotic possibility is the milk bush, *Euphorbia tirucalli*; this is undergoing harvesting and processing trials in Brazil and an experimental acreage has also been planted in California[33]. There is interest in this latter crop because it produces a latex containing hydrocarbons similar to petroleum which may be processed into a fuel oil.

The pressure of world food demand may well be such as to limit exploitation of energy crops but even if this is not the case, limitations may well be imposed by the demand for fertilisers to sustain yields, and for machines and fuels to harvest, transport and process crops. There may well be problems in producing both a net energy gain and energy at an economic price.

5.4 Energy from crop residues

Conflict with the requirements of food and fibre production is less likely to arise if the residues of food crops are used for energy purposes instead of growing special crops. The largest residue available in the UK is cereal straw and it may be assumed that the yield[4] is about 3.5 t/ha. About 3.8 Mha of cereals are grown and assuming a moisture content in the field of 30% this gives a straw dry matter yield of 9.3 Mt per annum. If directly burnt, this amount of straw of calorific value 18.4 GJ/t would have a gross energy value of approximately 170 PJ, about 4% of the UK's petroleum usage. However, a few years ago only about 38% of the straw produced was actually surplus to requirements[34] and the situation is probably little different today.

At present energy prices, collection of straw for the industrial manufacture of hydrocarbon fuels is not economic and the most practical thing to do is to burn and use the energy in straw on the farm. There are a number of cases where farmers are now using straw in addition to other materials such as logs and paper in slow burning furnaces which are draught controlled by the temperature of the water being heated. These boilers are now on sale commercially and the water is used for central heating and domestic purposes.

Straw burning also has possibilities for agricultural purposes such as drying grain and other crops and to provide heating for controlled environment houses. There is, for example, a grain drier operating in Germany which is fuelled by high density straw bales[33]. In the UK, the heat of combustion of straw has been used to dry both grain and straw in an investigation of whole crop cereals harvesting[35]. The whole crop was harvested by means of a precisiion chop forage harvester, dried in a rotary drier and then passed to a separator where the grain was removed and the straw fed to a straw burning furnace which supplied heat to the drier. There is more straw than is needed to dry the grain and it has been suggested that surplus straw could be stored and used in dry forage crops.

5.5 Energy from animal wastes

Animal wastes may undergo anaerobic fermentation to produce methane gas which can be used as a direct fuel. At the same time anaerobic digestion provides a method of treating farm waste to reduce odour while plant nutrients are conserved in the material left after gas production. Until 1950 a few gas generators were in operation in the UK and many more in France but they are now common only in developing countries such as India.

Production of methane in the UK has been a feature of municipal sewage works for many years, but what is feasible on a large scale is less attractive on a small scale and there are many drawbacks to farm operation. The first problem is the capital cost of the plant; the digestion process must be carried out in an air-tight vessel to which raw wastes are added daily and digested liquor is withdrawn simultaneously. The second drawback is that optimum digestion is obtained at about 35°C and this means that some of the gas must be used to heat the raw wastes and maintain the plant temperature. Typically, heating requires nearly 50% and 40% of the gas produced in poultry and pig manure plants respectively[36]. As generated, gas from pig or poultry wastes comprises about 69% methane and 30% carbon dioxide, with some hydrogen sulphide. While the gas can be used as it is, in suitably modified gas burning appliances and in engines, its use in some applications may require plant for the removal of carbon dioxide and hydrogen sulphide. For use in vehicle engines the gas must be compressed into cylinders and this requires special compressors and the use of power and also presents safety hazards. Nevertheless, at the University of Manitoba methane compressed into cylinders is being used to power a pick-up-truck[33].

In the UK, pioneering work on anaerobic digestion was done at the Rowett Research Institute and the North of Scotland College of Agriculture, where experience has been obtained in constructing and operating plant including a 13 m³ capacity digester using piggery wastes[37,38]. There are now at least ten anaerobic digesters operating on UK farms and others are planned. Some of these projects are ambitious and they merit description in detail.

The first[39] is in Suffolk where 160 ha of land supports 200 dairy cows (housed all the year round and bedded on chopped straw) and 4500 pigs (300 breeding sows). Slurry is produced all the year round at a rate of about 30 m³ per day with about eight per cent solids and is pumped to a below-ground reception pit which has a capacity of 110 m³. From the reception pit the slurry is pumped into the insulated digester which is a closed tank of enamelled steel with a capacity of 340 m³. It contains internal heat exchangers through which hot water is circulated to maintain the temperature at 32°C. The contents of the digester are agitated at regular intervals by a gas compressor which recirculates methane gas to a set of diffusers. As fresh slurry is admitted to the digester, digested slurry overflows into a 1000 m³ open slurry store which can hold about five weeks production of digested slurry and this is irrigated on to the land all the year round.

The residence time of the slurry in the digester is about ten days and the gas production rate is about 520 m³/day equivalent to about 90 gallons of diesel oil. A small gas holder, of capacity 5 m³, maintains the gas at a constant pressure of 125 mm water gauge.

The gas is used, as generated, to power a Ford 6 cylinder spark ignition engine driving a generator. Some 39 kW is generated continuously, of which 5 kW will be used to power a mechanical mixer which is to be added to the digester. The heat rejected to the engine cooling water and the exhaust gas heat are recovered to provide the hot water necessary for digester heating, and this amount to a continuous 51 kW. When the engine is cold, methane gas or straw is burnt in an external boiler to provide the necessary heat to stimulate production of methane. Automatic switch gear is provided to feed in the mains supply to the farm electrical load when the farm-generated supply is unable to meet demands.

At 2.8p per unit, the net output of 34 kW may be valued at £8300 per annum. About £25,000 has been spent on plant equipment and installation and this indicates a pay-back period of about three years. No allowance has been made here for maintenance or operational costs. (it is feared that the life of the engine may be low) and no credit given for the fertiliser value of the digested slurry. It is interesting to note that the farm bill for electricity prior to installation of the plant was about £6000 per annum and some additional oil was used for piggery heating. There is, however, the problem of gas utilisation since theseasonal pattern of gas availability and electrical demand are not easily reconciled without considerable facilities for gas storage, so caution is needed since the simple calculations presented here and in subsequent sections must be expected to prove optimistic.

In Yorkshire a 390 m³ digester is being installed[39] on a farm with a 500 sow breeding unit where the progeny are taken through to bacon. The digester system with generator set is supplied as a complete package, including automatic control and switching between mains and farm supplies, and is priced at £29,000. The net continuous electrical output will be 50 kW and has been valued at £12,000 per annum, indicating a pay-back period of about two and a half years.

Finally, in Kent a new dairy unit housing 320 cows is under construction which is designed to be self-sufficient in heat, light and power[40]. There is an anaerobic digester of 225 m³ capacity which consists of a conreted pit closed by a number of floating caps which are interlocked and allow both collection and storage to be achieved. This scheme is estimated to cost £60-70 per cow place and to produce energy to the valie of £20 per cow per annum. These figures indicate a pay-back period of about three and a half years.

5.6 Windpower

The British Isles are set in one of the windiest regions on Earth[41]. The winds are strongest around the west coasts of Ireland, Scotland and Wales with an average speed of 7.6 m/s. Other coas s have fairly strong winds at 5.6 to 6.7 m/s while rather lighter winds of around 4.4 m/s occur over most inland regions. Only in specialised locations and with small machines has the use of wind as a source of energy been a viable proposition, the exceptions being where no other supply is available and power is required in small amounts discontinuously.

A number of attempts are now being made however, to build cheaper and more efficient power producing rotors than hitherto and at Efford Experimental Horticultural Station in Hampshire, the Wind Energy Supply Company (WESCO) have built a twin-bladed rotor of 18 m diameter which should be capable of generating a maximum power of 150 kW. The essence of the design is a simple built-in blade pitch control, which enables the rotor to start up in a light breeze, increase its speed proportionally up to a predetermined wind speed and then limits it to a constant speed and power for any higher wind speed. This company has a number of proposals for making use of the power generated but in its simplest form, as at Efford, the rotational energy of the rotor is converted into hydraulic power and thence into heat energy which is intended to provide part of the heat for a glasshouse. Because of the uncertainty of availability of windpower it is necessary to retain the existing heating installation and only replace part of the demand by windpower. The viability of such a system hinges cirtically on the capital cost involved and it was in order to make rational assessment of such schemes that the facility was installed at Efford. Unfortunately, various difficulties have been experienced which has meant that the testing carried out so far has been very limited.

5.7 Reject heat utilisation

The possibility of utilising waste heat from power stations and industrial operations is one that is frequently raised in relation to agriculture, horticulture and aquaculture. A coal-fired power station with an electrical output of 2000 MW consumes the heat equivalent of 5500 MW of energy, disperses 3000 MW in the condenser cooling water and 440 MW in the flue gases. The temperature of the cooling water at outlet from the condenser is usually within the range 15 to 35°C which is only 15 to 20°C above the ambient air temperature. The possibility that the heat in this cooling water could be used to heat glasshouses within close proximity to power stations has been investigated in collaborative experiments between the Central Electricity Generating Board and MAFF at Eggborough Power Station in Yorkshire[42-44].

Eggborough is a 2000 MW coal-fired station and the experiments involved four polyethylene tunnel greenhouses of semi-circular cross section, each with a growing area of 200 m^2. Each house had a different means of transferring heat from the condenser cooling water to the greenhouse and the most successful of these was a convector unit in which water circulated in finned tubes over which air was blown by a fan. One of the major problems in growing crops such as early tomatoes is that the "blue-print" temperatures of around 20°C for day-time and 16°C for night-time cannot always be maintained with the condenser cooling water in the range of 15 to 35°C. In the circumstances reduced crop yields may have to be accepted or supplementary heat provided to maintain "blue-print" temperatures. The economic implications of these alternatives are not yet clear but the crop yields have compared favourably with those achieved under more controlled conditions at the nearby Stockbridge House Experimental Horticultural Station.

The results of the afore mentioned experiments are sufficiently encouraging to justify continuation of the work on a larger scale and the CEGB have now joined forces with Express Dairy Foods Ltd to erect and run an 0.2 ha modern, 7 m span glasshouse on a site adjacent to Drax Power Station, also in Yorkshire. The temperature of the station cooling water is said, on average, to be higher at Drax than at Eggborough. The glasshouse will be heated by fan-assisted finned tube convector units and will be divided into two halves, with different numbers of heat exchanges in each half. Crops will be grown using the nutrient film technique with the nutrient warmed by cooling water.

There is also interest in the possibility of growing edible fish in water warmed by reject heat and work is being carried out with both fresh and marine species; eels and carp are being investigated at Ratcliffe-on-Soar Power Station, Nottingham[45], while at Hunterston Nuclear Power Station, Ayrshire, plaice, sole and turbot are being grown[46]. There now exists a commercial eel farm at Drax in association with Rank Hovis McDougal.

A more fundamental modification to power stations has been proposed which would make use of reject heat by replacing the conventional cooling tower and condenser arrangement by a system of pipes buries un the topsoil of the ground surrounding the station. In Germany, an experiment is in progress[47,48] to evaluate the "Agrotherm system"; this has an underground network of pipes in which water at 32 to 35°C is circulated through 55 mm bore polyethylene pipes spaced 1.0 m apart and 0.75 m deep. Experiments are being carried out at four main sites with a total heated area of about 13 ha. At the largest installation at Neurath, measured surface temperatures are only a little higher in heated soil than in unheated areas but significant differences begin to appear below 30 mm depth.

In these experiments, increased yields have been reported for most of the crops grown, these include cereals (average increase 50%), maize (40 to 50%) sugar beet (up to 70% increase in the sugar content) and potatoes (20 to 60%). In addition to hard wheat, soya and ground nut were produced in an area where they would not normally have grown. Against all expectations, no additional irrigation was needed on heated areas. While it may be accepted that agricultural benefits have been demonstrated, caution is needed in interpreting the present results.

The cost of the system is high (in excess of £10,000/ha) and agriculturally, even with the increased crop yields claimed, it will be difficult to justify the installation unless a large proportion of its cost is borne by the generating authority. The system may be attractive to the West Germans because they have limited water resources and therefore accept that "wet" cooling tower systems may eventually be displaced by other cooling means. "Dry" cooling towers are considered to more expensive than either "wet" cooling towers or an "Agrotherm system", hence the attraction of the latter. In the UK there is a greater availability of cooling water and so the prime incentive to develop soil warming is lacking.

Many industrial processes, for example steel making, chemical manufacture, and cement making, have reject heat that cannot be used within the manufacturing processes themselves and which is at a higher temperature (in some cases a very much higher temperature) than is the reject heat from power stations. While such high grade heat is a more attractive proposition for use in applications such as glasshouse heating, harnessing the heat may not always be straightforward and different problems are presented according to the particular industry. Nevertheless, some interesting developments are taking place and it is worthwhile considering a few of these. One of the most promising developments is that at the Glengarioch Distillery near Aberdeen where waste heat from whisky distilling is used to heat an 0.2 ha block of wide span plastics houses, using a conventional piped heating system. The hot water is available at 60 to 70°C and a calorifier is installed to provide an alternative method of heating, should the distillery have an unscheduled shutdown. Another interesting feature of the development is that carbon dioxide, which is available at all times from the fermentation area, is piped direct to the greenhouse. During 1977 and 1978, crops of tomatoes were grown successfully as were small quantities of green peppers and aubergines. Cut flowers were produced during the winter of 1977/78 with over 100,000 tulip bulbs being planted. Expansion of the covered cropping area at Glengarioch is under consideration and a number of other distilleries are interested in setting up similar enterprises. The distilleries in Scotland are situated in areas where there is little horticulture and where the supply of vegetables incurs considerable transport costs; each one could support approximately one hectare of covered cropping area and would be ideally placed to suit the needs of the local population.

Other schemes are also under active consideration. One to which much publicity has been given is that between the growers Van Heynigen Brothers and the Mobil Company at their Coryton Oil Refinery. Here, the proposal is to use heat from the refinery boilers to heat glasshouses extending initially to 15 ha and later to about 30 ha. Elsewhere in the UK another grower and a large chemical company are combining in a reject heat scheme which will allow conventional heating methods to be used within the glasshouse.

This survey of high temperature waste heat utilisation would be incomplete without some reference to efforts by the British Steel Corporation to utilise reject heat from steel making. At Ebbw Vale, in South Wales, BSC have erected two Ruthner tower glasshouses together with a conventional 0.2 ha glasshouse block. The argument is that there are many situations where industry has waste heat available but little space in which to build conventional glasshouse structures. The Ruthner glasshouse contains a vertical mechanical loop conveyor system and the plants travel continuously up and down the tower with the root systems being periodically immersed in a nutrient solution at the bottom of the loop. Artificial lighting is also provided. The main advantages claimed for this method of cultivation are that plants are maintained constantly in an environment in which temperature, light intensity, humidity and carbon dioxide levels are kept within precise limits to optimise plant growth continuously throughout the year. A number of Ruthner towers have been built previously, mainly in Europe, but most of these appear to have been abandoned after a short while. The present experiment does not employ reject heat and this is of course not necessary in order to make the comparison between the two glasshouses. It is said that a tower glasshouse costs £400,000 against £50,000 for a comparable conventional glasshouse and that potential crop yields are the same from both types of structure. It therefore seems unlikely that the tower can be an economic proposition, even if relatively cheap reject heat were available.

5.7 Geothermal energy

Geothermal exploration of the UK so far indicates that the only resources available are likely to be low temperature (less than 80°C) water which may offer the possibility of heat for agricultural and domestic purposes[49] on a local basis. Work is in progress to determine heat production from boreholes in both Cornwall and Somerset. Geothermal energy is of course used to heat glasshouses in Iceland and New Zealand out in both of these countries the energy is available at a higher temperature than in the UK.

6 Conclusions

The main conclusions arising from this paper are as follows.

1. UK fossil fuel reserves could last for 150 years at present rates of consumption.

2. Energy prices must be expected to rise in real terms, thus reflecting the increased resources which will have to be put into producing energy as supplies become scarcer.

3. Agriculture, and horticulture even more so, already show signs of responding to increased energy prices through energy conservation measures, the adoption of alternative practices and the exploitation of alternative energy sources.

4. These responses can be expected to accelerate only as fuel prices rise in real terms so that alternative measures show economic benefits.

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INSTITUTION OF AGRICULTURAL ENGINEERS

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Professional manpower in agricultural engineering

B A May

1 Introduction

WHAT makes an organisation successful, a product widely used or a service be in great demand? The answers to such questions may be complex, but it is likely that people will feature as an important common factor.

This paper is about people, professional agricultural engineers, and their contribution to a key industry, agriculture.

Despite high unemployment there is a shortage of the right kind of professional manpower in Britain. It is therefore necessary that, in the right areas, we take steps to increase the numbers of those professional people who are most in demand and to increase the effectiveness of those already making professional contributions.

For efficient use of human resources, individuals must experience motivation through the meeting of personal needs. In terms of the group, need is associated largely with the roles which individuals are required to play. Perhaps the most important need for the individual, group and the country, is for a high level of productivity in industry.

The nature of these needs will be examined and the extent to which they are met in the course of the agricultural engineer's contribution to the development of the agricultural industry will be explored. Consideration will be given to some aspects of education and training for professional agricultural engineers.

Finally, some suggestions will be made relating to future professional agricultural engineering needs.

2 Personal needs

People are pre-eminently social animals and most of us spend most of our waking time interacting with other people. Our interactions are taking place in a contemporary world which, in terms of its impact on people, displays contradictory tendencies. On the one hand there is, for the individual, unprecedented opportunity for personal development; material standards of living for most were never higher, public services were never so complete and comprehensive, legislation was never so protective and educational opportunities beyond school were never so varied. Viewed from the opposite side, however, our world in many ways discourages individual initiative, threatens the quality of life, confuses personal values and encourages passivity and conformity. The very completeness of the social services is a temptation to accept passively that which the State hands out. There is much less incentive to plan ahead and a noticeable lack of a political and economic climate which rewards enterprise, endeavour and success, thus encouraging investment through increased confidence in the minds of financial decision makers. The contradiction may be described as the increasing need for intelligently responsible behaviour in a world that makes responsible behaviour increasingly difficult.

Personal needs may vary in nature and strength according to the individual's interpretation of this background. In general terms, however, there are five basic personal needs closely linked to motivation. *Physiological* needs recognise that we must alll eat, drink, sleep and have a roof over our heads for survival. We want to be assured that these needs will be met in future. In other words, we have a need for *security*. At the next level we wish to be accepted by our family, friends and colleagues — a *social* need. Beyond this acceptance our *ego* or sense of individuality requires that we are making some unique contribution in our work. Finally, we have a creative need for which we seek fulfillment in our activities.

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To meet these needs it is usually necessary for the individual to contribute to the work of a group.

3 Group needs

Two things largely determine the success with which a person interacts with others in a group. These are the contribution made which is in part in the form of skill and experience relevant to the work of the group, and secondly the manner in which the contribution is made. Interactions will also be affected by the size of the group, nature of the activity and accountability for the results.

Depending upon the individual's interpretation of personal needs and ability to fulfill those needs, one or more roles within a group will be sought or may be offered. The emphasis given to the roles played will depend upon the objectives of the group. In general there are four main roles. The *worker* performs the necessary operations to complete the work undertaken by the group. The *supervisor* organises and assists those undertaking the work. The leader performs a vital and often under-estimated role affecting the productivity of the group and motivation of its members. The *seeker* is active outside the group identifying and obtaining new work.

Two forms of leadership are generally recognised, one based on personality, the other focussing on the functions of leadership.

In the latter form, four typical styles of leadership behaviour can be identified, all of which may be practised by one *leader* in different situations. *Telling* involves the leader in identifying a problem, considering alternative solutions, choosing one and telling members what to do. Selling is as for telling, but instead of simply announcing the decision the leader tries to persuade the members to accept it. In a *consulting* style the leader gives the members a chance to influence the decision from the beginning. They are aksed to increase the number of alternatives to be considered and the leader then selects the solution he regards as most promising. The leader may participate in discussion and by *joining* agrees in advance to carry out whatever decision the group makes, within the limits given by his superiors.

Delegation is an important aspect of leadership in which the leader defines a problem and its boundaries. It is then presented to the group or individual to work out a sensible solution. The leader agrees to support this solution so long as it fits within the boundaries.

In choosing a particular style of leadership, three sets of forces need consideration, those in the leader, members and the situation. The leader who is aware of and can assess the relative strength of these forces is better able to choose the most appropriate pattern of behaviour.

4 The importance of productivity

For many individuals, their most important basic needs can be described collectively as the maintenance of an acceptable standard of living. To achieve this both for the individual and the country it is essential that there is a capable body of productive groups which is encouraged to achieve the highest possible levels of productivity.

The common objective of each group is to satisfy a market need for products or services in an economically viable manner. To do this each group is concerned with buying in raw materials, applying capital and human skills to increase their value and then selling the products or services at a higher price. The difference between the income from sales and cost of bought-in materials is called the value added per employee; this provides a realistic overall measure of productivity.

Adding together the wealth created by each group in all industries, produces the Gross Domestic Product (GDP). The GDP combined with overseas earnings gives the Gross National Product (GNP) which is the national fund available to finance the public services and to provide wages, salaries and other benefits which we take as employees. Our standard of living, both from the individual and national point of view, is therefore entirely dependent upon the efficiency with which we produce wealth in the wealth creating organisations.

5 Where and to what extent are these needs met?

In the developed world, agriculture is a science based industry — a factor which has contributed significantly to its present high levels of efficiency. As a consequence of its science base, agriculture is served by extensive research and development, consultancy and advisory inputs. These inputs have grown to include the application of advances in technology and management to agriculture, thus enabling significant inputs to be made by the agricultural engineer. With the exception of consultancy, these inputs in Britain are generally made from within the public sector.

The origins of agricultural engineering can be traced to the innovative farmer who, often assisted by the village blacksmith, provided the basis for the agricultural engineering manufacturing industry. This industry and its associated dealer/distribution network provides an important means by which the farmer can benefit from advances in technology through the sale of products and associated services.

There are thus two main areas of contribution for the agricultural engineer, through public services and manufacturing.

In view of the importance of productivity, the agricultural engineer should be contributing actively to the manufacturing industry. A general characteristic of the industry is the low added value of the products which, in association with low volume production and often small size of company, leads to limited wealth creation. As a result of this the retained profit necessary for the development of the business and subsequently the money set aside to cover the depreciation of existing assets is used to meet other demands and the future of such business is increasingly put at risk.

These factors impose limitations on professional engineering inputs. Failure to satisfy creative need can be a source of frustration for the individual. Successful innovation is, however, primarily a function of skill rather than available finance. It should therefore be possible to reverse adverse business trends through application of the right skills to increase productivity in value added terms. This may be achieved in several ways such as improved design leading to higher quality, better performance, increased reliability, economy in the use of materials, meeting delivery dates, and improved marketing and selling in a wider area, especially overseas. The effect of this is to increase the value added which gives the opportunity to pay higher wages and salaries, to increase the level of investment and thereby strengthen the company's competitive position and future business security.

For effective application of professional agricultural engineering skills in the manufacturing industry the individual must understand and be able to take account of the economic environment within which he works. He must be able to adjust to and work within the constraints which economic and legislative forces produce. He must be aware of and be able to overcome the problems arising from patents and patent law. He must meet the heavy demands placed upon personal qualities and be capable of undertaking and working within predominantly telling and selling styles of leadership. These styles are usually necessary in support of the dynamic and response approach which is essential for success in the competitive business world. He must accept that the level of accountability and risks are such that his personal needs for security and survival may sometimes be threatened or at best difficult to achieve.

The challenge to the individual in industry is consequently great, but at the same time it can be very rewarding. Whether in planning, design, development or marketing there is a concentration of the mind and a sense of urgency and positive achievement at a level rarely experienced in the public services sector. Higher order personal needs are capable of being satisfied. Unique contributions can be seen to be made when finally incorporated in a production model or associated services. For this to be achieved there is the added satisfaction of knowing that the many constraints have been successfully overcome. Opportunities do exist for fulfillment of creative need by introducing innovation through imaginative application of professional skill. For the well-motivated, opportunities can be created where they do not exist. To all this can be added the satisfaction of contributing to the farmers needs directly and in a material way, at the same time taking part in the wealth creating activities upon which we all depend for our standard of living.

The challenge for the manufacturing industry is to find, attract and keep the right kind of professional manpower which will meet the present and future needs and to find the right ways of encouraging the motivation necessary for high levels of individual performance. For an industry in which so many economic factors are at work, the piecemeal treatment of problems of professional engineering inputs can only provide a partial solution. Indeed, some of the economic and social forces present may be so strong as to predominate over other forces. Although there is a good case for reviewing professional engineering needs, progress nationally is only possible if there is progress on a number of fronts. This suggests that in looking at professional engineering needs, areas should be identified where the manufacturing industry is positively held back by deficiencies in engineering skills at present.

In the public services, the situation for the professional agricultural engineer is somewhat different. A sense of urgency is difficult to achieve since the pace of work is determined largely by the individual and the predominance of consulting and joining styles of leadership. The objectives of the group are more difficult to define and their achievement cannot easily be measured. Because of this, achievement of objectives can be less demanding on the individual and there is a constant risk of duplication of effort between groups. The seeker role is often replaced by the relatively passive role of priority selection in consultation with advisory bodies with less accountability and less risk of adverse effects on either the group or individual if wrong choices are made. Competition tends to be remote from the real world customer and is often confined to which group does the work. Performance tends to be measured by the manner in which the work is undertaken rather than by its impact in the agricultural industry.

In terms of personal needs, contributions through the public services to agriculture can be very rewarding. High job security ensures that physiological needs are met on a regular basis. The work is readily acceptable socially and generally there are many opportunities for satisfying a strong sense of individuality. Since much of the work is on a one-off basis the creative need is readily met. These differences in group needs and ways in which individual needs are met are fundamental to the kind of person the public service areas attract and the way in which these individuals develop. In combination with economic considerations they are also a basic influence on the ways in which public service areas and the manufacturing industry interact.

Advisory inputs are often made direct to the farmer in Britain and are based on a knowledge of currently available products and services from the manufacturing industry. For historical and economic reasons much of the research and development in technology is undertaken within the public services sector which must normally be applied in agriculture through the manufacturing industry. An effective link between research and development and the manufacturing industry is therefore essential. This link must not only take account of farmers' needs, but also recognise the needs of the manufacturer who further develops and builds the product. To achieve this, close, early and detailed associations must exist between agricultural engineers and other specialists in research and manufacturing respectively. There is some evidence to show that such interactions across groups in the public sector and the manufacturing industry are working satisfactorily. Much more is required in the future if real benefits to agriculture and to the manufacturing industry supporting agriculture are to be achieved.

In a general way, many of the points raised in connection with individual and group needs in manufacturing and the public services relate to consultancy in the private and public sectors respectively. Consultancy in the developing countries is an important area of contribution in view of the predicted opportunities which will arise in future for local manufacture and marketing of machinery and equipment. For many, there is also considerable personal satisfaction to be gained from helping other countries to meet national food requirements. The emphasis in consultancy, particularly in the public sector, is on planning rather

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than implementation. Frustrations can often arise for the consultant, including the professional agricultural engineer, when implementing plans which must be compatible with social, political, economic and infrastructural constraints. Consultancy is therefore a demanding area of contribution for the individual and group. The important need in future, particularly in the public sector, will be for more emphasis on implementation producing worth-while measurable results.

6 Education and training

Compared with the previous decade, higher education in Britain has declined in the order of social priorities in the 1970's. Courses in the applied sciences and engineering fail to attract significant numbers of school leavers of the highest quality. Despite this, interest amongst young people in following careers in agricultural engineering at both graduate and technician levels is good and shows signs of increasing.

The education and training requirements are seen as providing for the development of a wide range of engineering skills including design, development and production. There is a need for engineers with management, financial and marketing abilities. In addition, a need exists for a number of different levels of skills ranging from technician to highly professional engineer. Engineers contributing to the agricultural industry should have a thorough appreciation of the farmer's needs and problems.

Because of the wide range of engineering skills required, the early training of professional engineers should be as broad as possible.

The relationship between performance at school, in higher education and subsequently in industry does not follow a consistent pattern. Ability in mathematics and physics is important, but no single educational background stands out as developing engineering skills better than the others. This suggests that engineering skills can be developed effectively from a range of different educational backgrounds. There are a number of reasons for this: the many different areas of engineering (and agriculture) require different philosophies and approaches; engineers themselves mature at different stages in their early careers; for postgraduate work, scientists may be recruited as well as engineers and it is important that the agricultural engineering field as a whole recruits from a wide base.

Rigid streaming of students within educational systems in the early years is not as important as the careful selection and development of potentially leading engineers in the early years of practical training.

The intrinsic skills of qualified agricultural engineers in the U.K. are of good quality. Graduates and technicians compare favourably with those in many other countries. There are two main areas in which the manufacturing industry, and to a lesser extent, the public services, are weak in making use of these skills. These are in the development of the careers of young graduates and technicians and in the provision of positive help to qualified professional engineers to develop their skills during their careers.

The young engineer's career should be more carefully structured in the early stages of practical training. The early years of practical training, leading to chartered status or technician qualifications are critical in career development. Educational institutions should become more involved in this practical training, possibly through further awards which can be taken only when practical training, as well as academic, is complete. For example, a bachelor's degree in engineering might be followed at a later stage with an additional qualification signifying the attainment of a professional status, perhaps awarded jointly with engineering institutions.

For qualified engineers it is important that they keep abreast of the most up-to-date developments in their fields. Short courses of duration from a few days to a few weeks present an effective means of keeping knowledge up-to-date. To develop student interest in relevant up-dating courses, the concept of modular short courses leading to recognised qualifications should be encouraged. Such qualifications might also be awarded jointly with engineering institutions or bodies representing industry.

It should also be mentioned that young engineers intending to work in consultancy overseas have important training needs which at present it is generally not possible to meet.

7 Some future professional agricultural needs

In Britain, the greatest single need for professional agricultural engineers of high calibre is in the manufacturing industry.

To meet the need, these engineers must be broadly trained to a high standard, possess practical innovative skills and have outstanding personal qualities.

To make effective use of these skills, some changes in management attitude will be necessary, particularly towards design and product development, product management and training. To help meet the risks associated with these changes, further Government assistance will be necessary, especially for the small company.

Professional agricultural engineers will also have an increasing role to play in machinery and equipment marketing and distribution if the competitive position and market share of the British manufacturing industry is to be improved.

In the public services, professional agricultural engineers working in research and development will need to give more emphasis to the medium term practical needs of the farmer in Britain and overseas, guided by marketing specialists and based on what the farmer is likely to be doing in the future rather than that which others think he ought to do. This work should, however, not be at the expense of longer term research and development programmes.

To make an effective contribution to farmers needs, engineers in the public services should be working as closely as possible with manufacturers and preferably have experience of working in the manufacturing industry.

In the development of products for overseas markets, professional agricultural engineers should have, or acquire, direct experience of the countries concerned. A knowledge of languages may also bw important.

There should be a much closer relationship between the agricultural planning and development work of professional agricultural engineers in consultancy overseas and subsequent implementation programmes involving manufactured products.

There is no doubt that the professional agricultural engineer has a vital role to play in the future development of the agricultural industry in Britain and overseas. In a diverse industry which is of fundamental importance across the world in so many contexts it is essential that more professional agricultural engineers of high quality are available to apply their skills as widely, flexibly and effectively as possible.

Field machinery and labour

M Nicholson

FARMERS use resources such as equipment, by-products of the food industry, labour, sunlight, land, energy, the waters above the firmament...... and so on, almost ad infinitum. I have decided to concentrate on three of these, namely wastes of various kinds, labour and machinery.

I have based my contribution largely on my own involvement in business and my own experience, so the logical starting point is to relate something about my farm, myself, my family and my business interests.

The farm

This occupies some 120 ha of Oxfordshire cornbrash land and was bought by my father in 1919 for £75/ha. The whole farm is in cereals, growing wheat and barley for feeding to pigs — we breed and finish some 3000 baconers a year for a supermarket chain. The pigs, machinery and labour are managed by Bucknell Farms ltd, which rents the premises from my four daughters. One son-in-law is in charge of the pigs and another manages the arable side of the farm.

The land is farmed by my wife and me on a 21 year tenancy, with most of the land work being done on contract by Bucknell Farms Ltd. The rent of £5000-6000 per annum is paid to my four grown-up daughters; Capital Transfer Tax and Capital Gains Tax are now being paid at a reduced rate so that the next generation can eventually take over with minimal worries about taxation.

Two sons-in-law, two other men and one student run the farm In terms of size it is neither large nor small (farms in the 125-200 ha range have remained an almost static 17% of all farms since the 1870's), however in terms of output I doubt if it is average since in about two years we should be producing £250,000 worth of pigmeat each year. It is worth noting that over the same period farms in the 200-400 ha bracket have risen from 10%to 20% of all farms and those of 400 ha and over from two per cent to ten per cent.

Special features of the enterprises

(i) Some fields have grown cereals continuously for 25 years and in the favourable 1978 season grain yields were the highest ever;

(ii) all feeds are prepared on the farm from 'straights', with considerable use being made of subsidised EEC surpluses of dried skimmed milk, fat filled skim and liquid skim;

(iii) extensive use is made of industrial fork lifts; twelve 1 tonne tote bins, with stands, placed at strategic points around the buildings, and over dry meal conveyors, to minimise handling. A strain gauge in the anchor pin facilitates weighing of all the materials handled, including pigs in crates; we commissioned this specially and at some cost;

(iv) All the pig slurry is separated and the liquid is applied to the land through an irrigation system.

Co-operative ventures

(i) Cambac Pig Sales, of which we are a part, has an annual turnover to one outlet of approximately £4,000,000, and uses two 300 hp Volvo lorries to transport stock in the biggest specialist pig trailers in use in UK.

(ii) Bucknell Farmers Grain Syndicate is run by five farmers of which I am one, it has storage for 1,500 tonnes of wheat (installed in 1965 for £12.50/tonne after grant, and with an annual running cost of £1.25/tonne).

(iii) Syndication and sharing of several machines including combines, ditchers, fertiliser spreaders, slurry tankers and trailers over a 15 year period.

Waste utilisation

(1) Man made wastes. Any pig enterprise which is aiming towards the 21st century must be prepared to accept by-products from other industries. Liquid wastes we have tried include whey, skimmed milk, brewery waste and 'time expired' canned beer.

Skimmed milk was at one time too expensive to use, however we have started to use it again because it is now heavily subsidised by the EEC and is cheaper, on a dry matter basis, than the equivalent mixture of soya bean meal and barley in the ratio 2:1.

Unfortunately, the brewery products don't suit our particular mixer, they also tend to go sour in the pipeline and upset the first three pens of pigs. Other farmers with different feeding arrangements find that they can use these materials very effectively.

Among the solid 'wastes' we have had some experience of using, it is again dried skimmed milk, and this material mixed with fat, that we are using most effectively, judged both in terms of both cost and performance. We think that we have adapted our enterprise to the situation created by EEC agricultural policies, in which unpredicted surpluses have to be disposed of by subsidisation.

(2) Pig wastes. An unfortunate consequence of producing pig meat is that effluent is also produced, indeed it has been calculated that our herd has a 'pollution value' equivalent to a town of 17,000 people. Eventually it will be equivalent to a population of 25,000. This is a formidable consideration; on the other hand the slurry has a balance of plant nutrients which makes it about ideal for winter wheat, when applied at the right time and depending on the nitrogen availability.

What then, should we do with our slurry? There are a number of possibilities including:

(i) dump it in a disused quarry;

(ii) select an area of the farm each year to be sacrificed and flooded ad nauseam;

(iii) install an NIAE tower digester to drive off the N and leave a small quantity of dry sludge which will contain the P and K;

(iv) install equipment to separate the slurry into solid and liquid components, then pump the latter over as large an area as possible to supply, say, 50% of the N and all the P and K required by the farm crops;

(v) generate methane from the fresh slurry and then choose one of the above alternatives for the residue.

My view is that options (i) and (ii) are totally unacceptable and would soon be likely to cause the closure of the pig enterprise by the health authorities. Option (iii) would probably suit someone with little land and with neighbours who would otherwise be exposed to unpleasant smells — to me it seems wasteful to intentionally destroy the N, however many pig units will find that this approach becomes essential to survival as regulations tighten. The P and K are too concentrated to distribute at correct amounts on the land.

We have opted to separate and irrigate, and we may eventually decide to try to produce methane sometime in the future. With an underground main and 500 m of Bauer pipe we are able to reach nearly all of the farm. For distributing the liquid we use a modified Rainamatic, first seen by us in its original form at a clean water irrigation demonstration some 3 years ago. Continuous modifications to the machine by the manufacturer in consultation with ourselves and other farmers has resulted in a machine that applies the liquid through eight low mounted anvil jets at the rates we require most of the year round.

We are convinced that this is the right approach when land is available, but I must add that at the time of writing we have just had three weeks of rain followed by severe frosts: at such times one would dearly love to resort to the discussed quarry technique. The remedy, of course, is to have adequate storage — for at least three months — but this is costly. An acreage of grass would also help.

Labour

In this section the first big question to be asked is whether, from a national point of view, we really want to use less labour than we do. If agriculture employs fewer men, can other industries employ them usefully or do they become unemployed or find work in non-essential sectors? I don't have the answers but I feel the question has to be asked; I can only tell you of some interesting incidents and something about my own yardsticks.

I believe that in general wherever you are and whatever your job

M Nicholson, farmer, Bicester.

Paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The Conference Centre, National Agricultural Centre, Stoneleigh, on Tuesday, 8 May 1979.

or calling you are paid just enough to keep you there without being too disgruntled or restless! In agriculture there are, I believe, two levels of this situation, one relevant to stockmen the other to general farm workers and tractor drivers.

The good stockman, especially the dairy herdsman, states his own price. Today some dairy men will not even come for interview to jobs offering less than £4500 with considerable perks. That is fine and fair, because the range in the profitability of large dairy herds (and pig herds) of similar size and type is so great that a good man can generate such a remuneration for himself in addition to all that his employer requires. The snag arises when he doesn't 'deliver the goods' — he can't easily be removed from his job and house and the whole relationship becomes sad and sour.

In contrast a suitably worded advertisement for a tractor driver/general farm worker position with a house provided would bring in a mass of applications from army short service regulars, drivers, mechanics, factory workers — people from all walks of life. An adaptable man with a few training courses behind him could eat the job; supply exceeds demand and so they are not paid adequately.

The general principle however is that labour can only be employed when, if well managed, it can generate cash to pay for itself and leave a reasonable margin for the employer. In my own case we can prepare pig feeds which are on average £20/tonne cheaper than equivalent national compounders' feeds and £15/tonne below the price charged by local co-operative compounders. I could easily justify equipment and a man to prepare 20 tonnes a week, and at that rate he should also be able to handle the slurry and save more than his wage in N, P and K!

Norway has decided that eight per cent of its labour force should be maintained in agriculture. What plans have we for the 21st century? Would it be in the national interest to reverse the long established trend and begin to take on more people in agriculture? Does one throw away the automatic wet feed plant and go back to feeding by hand? Do we need to automate parlours to enable us to use one man instead of two? This is a new philosophy that has not yet occurred to the farmer in this country.

Machinery

In theory it should pay to work machines for long hours, it should pay farmers to co-operate and form machinery syndicates, and there should be a place in the scheme of things for contractors. A machine is a resource; it takes another resource, money, to acquire it and we should all be interested in using both efficiently. There are, however, snags.

In our own case, and there are many like us, we have grown more and more cereals: this year we are almost 100½ winter cereals.

These are some of our options for the September/October rush period that this system has created:

- (i) use medium powered tractors, say 75 hp, for our 100 ha of cultivating and drilling. This is the traditional approach;
- (ii) use a large secondhand tractor — an apparently over-capitalised approach;
- (iii) make use of a contractor;
- (iv) join with neighbours and do the job co-operatively.

We have chosen to change from (i) to (ii), will move to (iii) for specific jobs but are unlikely to adopt (iv).

Taxation considerations and inflation have a major influence on the way farmers invest in equipment, and the decisions taken on big farms have an effect further down the scale. It seems to pay those large, profitable farms to change equipment regularly because of the tax concessions on new machines and the high secondhand values which cushion the cost of new machines.

We have found that our 100 hp tractor, bought secondhand at two years old, has revolutionised our lives; when necessary we can work longer hours each day without fatigue. This, combined with the increased hourly output compared with our earlier tractors, has dramatically increased the area we can cultivate in a busy period.

Until recently we were given to thinking that to justify its existence the top tractor on a farm should do 1000 h annum. Now we are thinking more in terms of 400 hours a year and were a little uneasy about this until we heard an ADAS advisor, speaking on the radio, express the view that on a suitably sized family farm a 200 hp tractor, costing £40,000 to £50,000, could probably be justified even if it only worked 350 hours per annum.

Our problem is to know what to do in one or two years time — do we move our machine on down the line or do we keep it 10-15 years when it will be obsolete but not worn out? It seems hard to believe it can become obsolete it is so much better than anything we have experienced.

Contractors and co-operative arrangements

No discussion about machinery utilisation would be complete without reference to contractors. There are, of course, contractors and contractors; many of those who simply provide outside strength to help farmers do jobs they ought to be able to do themselves have had a difficult time recently. The summer and autumn of 1976, in particular, saw several contracting businesses fold because work was so easy that even the pontificating NFU Committee man and the man who goes to market twice a week managed to get their work done without help.

The contractors who survived and are flourishing are the efficient, highly capitalised men who can do specific jobs so much more quickly and effectively than any farmer. Jobs which fall into such categories include:

- (i) silage making, including maize harvesting in a wet October/November;
- (ii) whole farm manure handling, especially on large dairy and beef units;
- (iii) hedging while soil conditions are suitable;
- (iv) whole farm straw handling (not combining, partly because of the lack of high throughput reception facilities);
- (v) winter spraying herbicides on winter cereals grown on heavy land. (This last example is a very topical one, and a local farming group has recently guaranteed a new helicopter operator 4000 hectares of winter work each year).

Before ending this section I must add that if anyone utilises the equipment resource effectively it is the progressive, organised contractor.

Co-operation

Finally I must mention co-operative ventures, because there also offer scope for good resource utilisation. Here I speak as something of an 'expert' for every two years I take part in a seminar on the subject (held in Oxford and organised by the Plunkett Institute for Agricultural Co-operation). This is organised for overseas 'co-operation'.

Based on experience gained in Cambac Pig Sales the criteria for success are:

- (i) a common need;
- (ii) a sustained need;
- (iii) decisive leadership
- (iv) not too democratic;
- (v) common interests of members — a measure of 'clubbability' (for this organisation close proximity to one another is not essential and the members at the extreme edges of the area are about 60 miles apart);
- (vi) loyalty based on commercial viability, not on emotion;
- (vii) the realisation that big is not necessarily beautiful.

Implementation is not always easy; at the moment our grain syndicate stores 1500 tonnes and it might seem a logical step to now grow the crop co-operatively. The steps might be to first buy a baler and a set of straw handling equipment, then to jointly own the combines, then to operate them as a fleet and perhaps even to own the crop co-operatively and share the proceeds.

We have had a grant aided feasibility study done on the grain group and I will close by mentioning some of the points brought out. There are the obvious problems of soil variability, differences in crops with one member wanting simply to feed everything to pigs while another grows seed crops on land that has been down to grass for cows and yet another is not bothered about high rates of work, and so on. By far the most interesting point to be brought out, however, concerned the equipment presently carried out on 600 hectares (400 arable, 200 grass). This included:

20 tractors
5 combines
4 balers

and 16 cars!

Are we able to carry this load because we are, individually, so amazingly efficient? Would a single farm of 600 hectares be so much better and ought we to overcome the problems mentioned earlier and combine our businesses? In fact the biggest stumbling block lies in the taxation problems that arise both on annual profits and inheritance. A single crop co-operative involving not more than one third of a farm acreage can be very successful. My farm with 100% cereals makes this almost impossible.

Preparing this paper has made me realise how very individual is one's approach to the whole subject of resources, and it has made me consider our situation with care. I wonder how many other farmers bother to do just this?

Processing plant and by-products

Summary of paper by I Bjurenvall

WHOLE crop cereal harvesting allows cereals to be cut at the optimum time, almost regardless of weather conditions, and given suitable equipment each component of the crop can be put to its most appropriate use. The developments described by Mr Bjurenvall were in fact undertaken mainly because of the potential of the non-grain parts of the crop. He has been responsible for developing the Kockums system for harvesting, transporting, drying and separating whole cereal crops into various fractions. This includes a self-propelled harvester with a chopping mechanism which has been developed to produce freely flowing material and to minimise the level of grain damage. Road vehicles are used to haul specially designed 40 m^3 containers to a central processing plant.

Investigations showed that it was not satisfactory to dry the whole crop in one step in a drum drier. It is now partially dried to facilitate separation before the various fractions are dried by different means; this allows the grain to be used for any normal purpose whilst the light fraction, consisting of leaves, light grain and light pieces of straw, can be used for cattle feed. The 'pure' straw can be put through a gasifying process and the company is developing a plant which, by 1980, will process sufficient heat from 40 — 60% of the straw to dry the crop and to produce all the electricity the plant requires.

A major part of the work, however, is the development of chemical processes which use straw and yield valuable products; even in Sweden the possibility of producing cellulose from straw is attracting attention because of the high cost of extracting timber.

I Bjurenvall is President Kockums Construction AB, Sweden.

From a paper presented at the Annual Conference of The Institution of Agricultural Engineers, held at The Conference Centre, National Agricultural Centre, Stoneleigh, on Tuesday 8 May 1979.

Efficent use of resources: implications for the agricultural engineer

Edited summary of discussion

Mr F D S Newman (HSE) wished to know if Dr White had any recent information regarding the costs of methane production on the Suffolk farm shown on his slide. The plant had not been particularly reliable since its installation.

Dr White agreed that there had been some problems in operating the unit. In autumn of 1978 a fibrous crust occurred on the liquid in the digester vessel. This had been anticipated as a possibility but stirring by circulating the methane had been expected to minimise the problem. It was evident that a mechanical stirrer requiring about 5kw power input would be required. The cost figures which he had quoted were not entirely theoretical and had been confirmed in practice.

Mr T C D Manby (NIAE) asked whether solar energy could be used to improve the output of methane plant in the UK.

Dr White felt that it would be possible using solar panels and a heat exchanger but that alternatives such as straw burning furnaces would probably be more viable economically. The balance of heating and ventilation requirements in piggeries tended to give a constant energy demand over the year, part of which could be supplied by methane.

Mr G F Shattock (consultant) commented on the need for greater reliability in methane production systems. He felt that Mr Bjurenvall was correct in separating the constituents and using the valuable ones. He recommended the screening out of coarse solids to improve the efficiency of the system, leaving the fine solids in the liquor to give five per cent dry matter. Composted solids could afterwards be sold.

Mr C F H Bishop (MAFF) enquired whether odour reduction was a reason for installing methane plant.

Dr White replied that the anaerobic first stage considerably reduced the odour although the BOD would still be too high to permit the release of the liquid into waterways.

Mr J G Shiach (NOSCA) observed that it was only now that enough information was available to enable a farm anaerobic digester to be designed adequately. After six years experience of running a digester in Aberdeen it was now possible to advise on design and this was being done in the case of a large scale commercial development.

Mr W C T Chamen (NIAE) asked Mr Bjurenvall if the chopping of straw in the field was the correct approach. Would it not be better, in view of having to separate the crop before drying in the plant, to chop the straw after separation. Mr Bjurenvall had indeed considered the possibility — computer programmes had been run on all variations and the solution adopted appeared to be the best one. Transportation and handleability by conveyors are problems which must be satisfied.

Mr G Shepperson (NIAE) stated that the Kockums Construction work on whole crop harvesting was a long term and capital intensive project and depended on a high price of straw for processing. Hence it was a system for large farm units of co-operatives, perhaps in ten or 20 years time. Notable developments were being made here in the UK, at Sutton Bonington.

Mr B Wilton (University of Nottingham) expanded on this theme explaining that the Sutton Bonington work, in which he was involved, was currently concerned with forage harvesting of the whole crop and subsequent separation of the damp crop into three fractions — grain, heavy straw and a mixture of light straw broken grain and other small material. The grain will be dried by burning the heavy straw and the intention is to ensile the third fraction with a chemical preservative. It is anticipated that a farmer could employ this technique using his current grass harvesting equipment plus a farmstead separating/drying/ensiling facility. He would thus use his harvesting equipment for two crops spread over a five or six month period and could use his labour at a steady rate throughout the grain harvest instead of contending with the intermittent stop/go progress which is associated with combining. He would also use all of the crop in one way or another.

Dr White replying to a question from Mr Carnall (Bonser Engineering Ltd), said that in his view there would be a move towards energy saving in packaging and that it was still economic to apply increasing amounts of fertiliser although the returns were diminishing. Production of ethanol from crop residues, for addition to fuels, was mentioned but at present was stated not to be economic. To a question from Mr W S Shattock (Consultant) on industrial and agricultural experience for students during vacations, Professor May observed that, in the case of agricultural engineering students, the appropriateness of the course increased the ease of establishing contacts in industry and in agriculture. Mr W James (Ryecotewood College) found that there was little problem in obtaining vacation work but he would always welcome ideas, particularly related to research and development projects.

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Mr J G Shipman (ATB) asked whether industry was in general succeeding in developing its staff in all areas of activity. Professor May replied that, from his extensive contact with industrialists during the last three years, he had concluded that scope existed for more staff development through such activities as short courses organised by specialist groups with resources and expertise in the technical and managerial fields.

Mr T C D Manby asked if Mr Bjurenvall would comment on the magnitude of his project operation and how best to sell the idea. Mr Bjurenvall was firm in explaining that there was only one way — the operation must be profitable. They were having to turn away farmers who wished to make deliveries to them. They processed thousands of tons of material. However, this operation was a complement to other techniques — it was not the only answer.

Mr J A C Gibb (University of Reading) enquired whether optimal use of resources was sometimes inhibited by the effects of taxation for other financial legislation.

Mr Nicholson felt that there was a rush buy cultivators before the financial year ended often resulting in hasty and sometimes unnecessary purchase. The process of averaging over two years, however, did help to alleviate this situation.

Mr J V Fox observed that the 100% machinery write-down in UK farming affected the timing of demand for machinery but should not result in inappropriate machinery being purchased, provided that care was taken in selection. He mentioned the roles of financial incentive and job satisfaction as aids to motivation.

Mr T C D Manby enquired about the design problems encountered during the Kockums project.

Mr Bjurenvall stated that since the problems were unconventional a wide range of expertise was consulted. He stressed that his company was concerned more with the overall process and potential utilisation of the raw materials than with the building of plant and equipment.

Mr W E Klinner (NIAE) felt that the value of the light straw fraction — stressed on many occasions by Mr Bjurenvall — could be utilised if combine harvesters were modified to place the sieve efflux on top of the straw swath. Much of the chaff would then be picked up with any straw harvested. If the straw is destined for burning, the presence of the chaff is likely to improve the effectiveness of the burn and also help to destroy more weed seeds.

INSTITUTION OF AGRICULTURAL ENGINEERS

1981 Conference Programme

Spring National

Date:	**17 March 1981.**
Venue:	Wye College, Kent. (In association with London/Kent Branch)
Subject:	**Engineering in Horticulture.**

Annual

Date:	**12 May1981.**
Venue:	To be decided.
Subject:	**Engineering for Beef Production.**

Autumn National

Date:	**13 October 1981.**
Venue:	To be decided. (In association with North Western Branch)
Subject:	**Engineering for Intensive Vegetable Crop Production.**
All enquiries to:	Mrs Edwina J Holden, Conference Secretary, Institution of Agricultural Engineers, West End Road, Silsoe, Bedford MK45 4DU.

The second review in a new series with a "practical" flavour

Tramlines – the right lines?

W D Basford

HAVING long since lost them from our streets, and living in an age when more sophisticated guidance systems are commonplace, it is a surprise still to most laymen that tramlines should turn up as a guidance system for farm crops, at least in spirit anyhow. However, all concerned with agrochemical application realise the need for a reliable system of swath matching if chemicals are to be applied with any precision and it is doubtful if many of the systems employed at present meet this need entirely.

Present situation

Evidence of inaccurate swath matching can be seen every year following fertiliser and spray application. The extent of errors made has been quantified several times, most recently in the ADAS Survey "The Utilisation and Performance of Field Crop Sprayers 1976" (Ref 1), 91 sprayers operating under commercial conditions were studied, 82% of which had maximum errors in swath matching of over five per cent (ie one nozzle spacing approximately). Overlapping formed the majority of errors, 26%of operators doing so by more than 15% of swath width. Standards of swath matching with fertiliser spreaders are likely to be of a similar order though actual swath widths may be lower.

The penalties for overlapping with sprays can be seen directly as waste of chemical, and indirectly in suppression of yield by chemical damage, shrivelled grain etc. Where fertiliser is concerned, incomplete application through underlapping has shown losses in the order of £12 per hectare, whilst overlapping wastes fertiliser and gives uneven crop growth.

Over the years the sprayer and spreader operator has had available to him several systems of swath matching, the most prominent being fixed markers, trailing string, foam or dye markers and radio controlled automatic markers.

More recently there have been developments in France employing a ground marking system on a 12 m boom to give a permanent mark before crop establishment. This could, in certain situations, represent a new concept acceptable where other more conventional means of marking are not. It is likely that, in future, developments in aircraft guidance systems could be employed with land machines, and indeed, it is believed that simple systems exist. But such systems are, at present, outside the scope of normal agricultural operations, so that tramlines can be seen as a real aid in giving the operator a "line of sight" system by which to drive.

Returning to the ADAS survey, it is interesting to note that 51% of operators employed no swath matching aid whatever. Work at the National Institute of Agricultural Engineering has shown that foam blob and dye markers can improve the accuracy of swath matching, (Ref 2), but the Survey showed that while some operators without any aid achieved high standards of matching, others even when using foam and blob markers, were unable to drive accurately. Radio controlled automatic markers are another possibility but still to be proved in the UK, and spray operators will readily admit to requiring better systems of swath matching.

Recent attention to continental systems of cereal growing, notably those techniques outlined by Professor Laloux and those practised in the Schleswig-Holstein area of Germany, have focussed attention on a need to drive through crops frequently and at late stages of growth. From these techniques (and such systems as the "bed system" in horticultural crops) has emerged a rational approach to implement systems which allows semi permanent guide marks in cereal crops to be established. These guide marks are now well-known as "tramlines", but defined as " intentional gaps established during drilling of a crop to serve as wheel paths for later operations." (Other systems not involving the drilling operation are briefly described later.)

The basic concept of tramline working is that the working widths of drill, fertiliser applicator and sprayer are in exact multiples (three or five times the drill width). The odd number of multiples allows both of a pair of tramlines to be established simultaneously on a single central pass of the drill, which contributes to high standards of accuracy. With this method tramlines are normally produced by terminating the seed flow to those coulters immediately following the rear wheels of the tractor.

An alternative technique is based on an even multiple of drill widths. This generally means that one only of each pair of tramlines is established on any one pass of the drill, the other line of the pair being produced on the adjacent drill pass. In many respects this is easier to do but can be less accurate in establishing the exact width of the pair of wheel paths. These techniques are fully illustrated and described in MAFF STL 189 (Ref 3).

Tramline formation mechanism

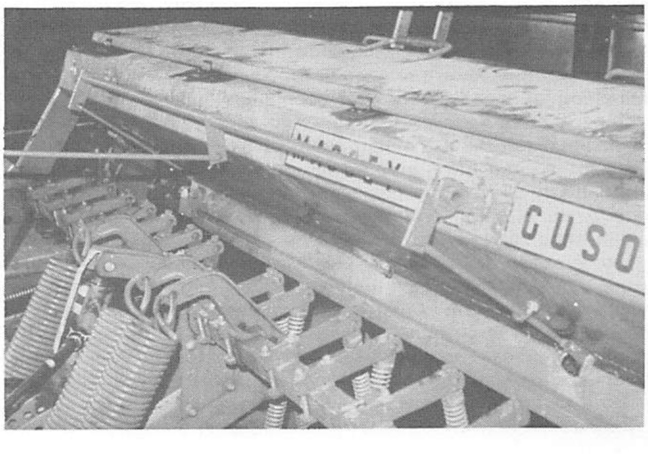
It is seen that seed flow in specific coulters must be stopped after a given number of passes of the drill. This can be achieved manually, or automatically or semi-automatically through a mechanical system. A large number of cereal drills incorporate a slide cut off above their external force feed mechanism as a standard feature. Whilst this is a simple means of stopping seed flow, some seed is retained in the feed mechanism and sown over the next few metres. This gives a "rough-ended" appearance to the tramline which, according to personal susceptibilities, may offend.

An alternative method is to interrrupt the drive to the feed to individual coulters by installing a simple clutch. Whilst this may be more expensive to arrange it gives a positive termination to seed flow.

Many systems have been developed to be operated by mechanical linkage, cable, hydraulic, compressed air or electro mechanical means. The simplest is a manually operated mechanical slide, the operator remembering the desired pass of the drill on which to operate the system. This clearly has disadvantages in that the operator has many other tasks to perform whilst drilling and his memory may not prove adequate. Once faults do occur, they are extremely difficult to identify and remedy during drilling.

A system finding much favour is a pawl and ratchet device adapted to count the required number of movements fof the drill-coulter raising mechanism. This can then either indicate to the driver the required pass on which to stop the seed flow, or indeed be directly linked to operate the slide cut-off automatically. The need to raise the coulters at an unscheduled time (to clear a blockage, or to replenish the hopper) necessitates the inclusion of a facility to discount such a movement or to reset the system. In practice this often means manually cancelling the movement of the

Home-made hand-operated cut-off system which is simple and effective



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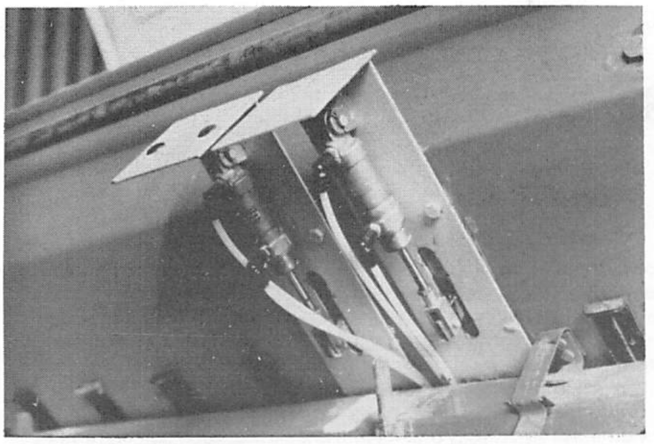

Pneumatically operated cut-off for slides. Two are necessary on this narrow drill

counting device or raising and lowering the coulters whilst the drill is stationary until the correct place in the sequence is reached.

Electronic memory aids are available, the drill mechanism operating a trip switch through count-down relays, finally indicating to the driver or operating the cut-off directly at the correct point. One version of a memory aid is installed in the tractor cab and senses tractor direction relative to magnetic north. Headland turns are then counted and indicated to the driver on a display.

Any system which reduces the operator involvement is to be preferred but there are varying schools of thought as to whether routines associated with headland turning are more reliable than those associated with other activities such as raising or lowering of coulters. A list of available equipment for drill modification is obtainable from all ADAS Mechanisation Advisory Officers (Ref 4).

Implement tramline widths

The major problem associated with tramlines is the module on which to work and the relationship of implement widths to this overall width. Fertiliser spreaders often are the most difficult to modify to meet the chosen width but within the last two years a proliferation of both centrifugal and pneumatic spreaders has enabled 12 m (40 ft), the most common width, to be met. Pneumtatic types, which may cost four times more than centrifugal models, are in particular becoming very popular in some areas.

Sprayers are becoming increasingly available at 12 m width and in fact many were available at just under this figure for seveal years prior to the present interest in tramlining. Extension of booms is a relatively easy task so long as pump capacity is available; likewise the blocking of nozzles is a simple task. A width of 12 m may still be too small for some operators, particularly where liquid fertiliser is being applied. Here developments have included the production of 20 and 24 m booms with vastly improved boom suspension systems, to allow increased acreages to be covered. Nevertheless in some cases, it is doubtful whether increased boom width is necessarily an advantage since tank size may prove the limiting factor governing overall output during the day. However, it is recognised that once tramlines or crop marks are established the matching up of these very wide booms is simplified.

Taken a stage further, some operators suggest that the very wide booms may remove the need to establish true tramlines as unsown gaps in a crop. The amount of damage caused by wheels, (particularly narrow row crop type) relative to the width covered in one pass, is small and therefore so long as a mark can be established by which to drive this may be adequate.

Some cereal drills may not give a suitable module on which to work when establishing tramlines at four, five, or six times the width of the drill. However, in many instances slight variation of the sowing width is possible, and this can significantly reduce the problem. Some manufacturers of spraying equipment are now able to offer tailor-made booms to reduce the problem of matching drill widths and this is proving encouragement to the adoption of tramline working. Drill coulter spacings varying from 100 mm to 178 mm (4-7 in) (most commonly centring on 111 and 178 mm) place limitations on the adoption of the tramline system. Stopping seed flow on such row widths leaves nominal gaps ranging from 200 mm to 356 mm (8-14 in). When planning a tramline system the tyres intended for use within the tramlines must be considered and a practical allowance made to allow for tyre deflection, driving error, etc. to give the required spacing. An allowance of 50 mm either side of the tyre will achieve a sensible gap for this purpose, eg a 200 mm (8 in) tyre requires a 300 mm (12 in) gap whilst a 300 mm (12 in) tyre requires a minimum of 400 mm (16 in). Obviously this is greater than the nominal gap achieved by blocking one coulteron a 178 mm spaced row. This problem also occurs if the narrower row spacings are used when often two rows need blocking. Slight re-spacing of the coulters on their mountings may provide the clearance required. Wheel dividers have been used to assist with parting the crop. This obviates the need for wide row spacing but dividers are by no means universally used. Running over the crop whilst turning, particularly with trailer sprayers, has been cited as an unsatisfactory part of tramline operation. However, crop dividers on the front tractor wheels which turn with the steering have made a contribution to parting the crop reasonably for the tractor passage. "Running-in" of trailed wheels is a factor which most people accept, as unless the draw-bar to hitch point distances varies significantly the run in of the trailer cannot be altered much without major changes in draw bar geometry.

Wheel track widths may also limit coulter selection since the most common row widths for sugar beet, potatoes, etc, may not match the multiples of cereal rows.

Variations on tramlines

During cereal aphid attacks particularly, those farmers not using tramlines or those who use narrow wheels have raised doubts as to the necessity for tramlines relative to the damage question. However, the major advantage of tramline operation is in improved accuracy of application of crop chemicals and fertiliser, and many variations of tramline working have been considered.

Reduced cost and reduced reliance on machinery supported interest in other ideas to provide a mark through the crop by which the tractor driver may drive. These other marking operations may not be the same as "tramline" operation, but the objectives are of course identical. Common alternatives are:—

a. spraying out cereal rows
b. continuous wheeling
c. hoeing out cereal rows
d. permanently blocking one cereal row
e. dribble feeding one coulter
f. spacing coulters wide
g. automatic blocking of one coulter
h. driving wide.

Where the techniques listed above involve additional operations this may be a disadvantage. Further marking out of fields by hand may also not be as accurate as normal driving when drilling. Where the objective is to run in the same marks and run down a portion of the crop (b, c, d, e, g and h) this loss in crop must be viewed in relation to the stage at which the crop is wheeled.

The other serious alternative is the aircraft or helicopter, for when available, the task is completed swiftly with good swath marking techniques and no wheeling problem. The availability will obviously vary throughout the country depending on workload, contracts and location.

Both radio controlled ground markers and electronic sensing of foam blob location from sprayer boom ends scanners are in the process of development.

Future

The UK has seen a very rapid uptake of the technique when judged against other swath matching systems. My own contacts in Nottinghamshire lead me to believe that ten to 15% of the cereal acreage is now tramlined, where nothing was done three years ago. Enquiries for assistance on adopting tramline operations are still being received regularly. Tramline operations should be judged as an aid to swath matching, as reduction damage is offset by loss in yield due to gaps left as tramlines. Experimental work both by ADAS and others has shown that these factors balance. Positive advantages come from accurate marking, increased work rates (approximately 50% more), simplified operation, more even maturity in the crop and opportunity for both inspection and subsequent improved timeliness.

Wet years, when it may be very difficult to establish tramlines, coupled with increased costs, rationalisation of equipment, problems with pre-emergent sprays, and reduced drilling rates have all been suggested as major disadvantages. In the initial stages of tramline adoption, drilling rates may be slightly lower but if an automatic system is selected there should be no reason why drilling rate is affected. Equipment is now available from 3 firms to make soil marks whilst drilling, to serve as guidelines for spraying of pre-emergence materials. For those people not concerned with late damage this simple development may also preclude the need for coulter blocking. In the first operation the soil marks can be traced, leaving wheel marks which are followed for all later operations.

Developments in the field of electronic sensing of foam blobs, radio control, remote controlled television, aircraft, airctaft guidance system, etc. all hold great interest for the future, but all use fairly sophisticated technology which may not be readily adaptable into the true agricultural field. More immediately, however, the combined use of a simple coulter blocking mechanism to leave tramlines coupled possibly with the use of pre-emergence marking equipment, can lead to a significant improvement in application standards. There are many developments in spray application equipment but all the methods under consideration at the present will still demand high standards of swath matching. The tramline system of working is available now, does not necessarily incur a large expenditure and within one season can show large dividends in terms of timeliness of application, chemical saving, and increased quality of cereal sample. When one considers the rather low standards indicated by the ADAS survey, an increase in overall yield is perhaps not too far beyond imagination and could easily recoup the cost of adoption of even a fairly sophisticated tramline system.

References

1 — Farm Mechanisation Study no 29 "The Utilisation and Performance of Field Crop Sprayers 1976" published by MAFF.

2 — NIAE Report No 8 "Investigation into the Accuracy of Matching Sprayed Swaths in the Field" — D C Lawrence, October 1973.

3 — Short-term Leaflet No 189 "Tramline Systems for Cereal Production" — published by MAFF.

4 — Tramline equipment available — W D Basford, ADAS Nottingham, November 1977.

Books

Farm Workshop and Maintenance

FARM WORKSHOP AND MAINTENANCE is the second edition of the book first published in 1972 and based on the *Farmers Weekly* series 'Workshop'. The book is aimed at the many farmers who feel that, with some guidance, they will be able to cope adequately with the many maintenance and repair jobs on farm machinery without calling in the expert.

The first section deals with the selection and use of basic hand tools, illustrated, as is all the book, with many black and white photographs and clear, simple diagrams. This is followed by a rather more theoretical section that answers some of the questions that are often raised by farmers; for example, the derivation and meaning of horsepower. The opportunity has been taken to metricate the text, mostly successfully, but quite rightly imperial units have been retained where it is thought appropriate.

Overhaul of common machines such as mowers and balers is attended to individually whilst there is also a section dealing with pre-operation checks and breakdowns. It is in these sections that one appreciates the value of the index. The somewhat disjointed layout and presentation reflect the origins of the text as a weekly series.

With the implications of the Health and Safety at Work Act still prominent in many peoples minds it seems unfortunate that the opportunity was not taken to update several photographs that show hazards that are now unacceptable.

In general, a well illustrated book with much useful information to supplement machinery handbooks but one which would have benefitted from a more extensive revision.

Farm Workshop and Maintenance, second edition, Crosby Lockwood Staples, Granada Publishing. £4.95 in hardback.

DH

Livestock Health and Housing

IN the past few years, there have been a number of publications on specific aspects of animal health, housing and management, and it is inevitable that in condensing much of this work, a considerable amount must be omitted. *Livestock Health and Housing* appears to suffer from this problem and yet at the same time, is very detailed in some other aspects. Consequently it is difficult to see for what market this book is designed. For any specialist in livestock housing, or anyone requiring depth in a subject, it is likely that they would refer to other publications such as FBIU or NIRD material. For those requiring a general appreciation, the detail given on Ventilation for instance, is excessive and leads to an imbalance in the book. Manure disposal is dealt with somewhat summarily, and whereas stock water requirements gets a whole chapter, feeding systems, silos and mechanical feeders go virtually unmentioned. It is difficult to follow the referencing since in some instances references used in the text are given at the end of the chapter, whereas in other instances, particularly diagrams, there may be general references only. *Livestock Health and Housing* has considerable potential if, in the next edition, the balance is altered and more information given on modern developments and systems.

Livestock Health and Housing, by David Sainsbury and Peter Sainsbury, Published by Bailliere Tindall, London, 1979.

MPD

Materials Handling in Farm Production

THIS 120 page book brings together performance data published by ADAS, the NIAE and other authorities and details of techniques for examining the work to be done in handling and transporting materials on the farm. The style and presentation make what may to some people seem to be a dry academic subject, which as Butterworth himself says is partly a matter of common sense, into something of interest for farmers, students and advisers. Although I rather doubt whether many farmers will apply the discipline of drawing block diagrams of their materials movements, the book will give a grounding on the technical terms used by the "experts".

Some of the ideas put forward by the author may well be new to many readers, for example the use of intermediate bulk containers for the direct self-feeding of stock. My main regrets are the shortage of firm advice on safety, for example in the stacking of ton boxes of potatoes, and on the effect which the choice of the handling system is likely to have on the costs of buildings and the expensive concrete surrounding area.

The book is well illustrated with drawings of materials handling equipment at work which enable the author to save words in his descriptions of the features and use of equipment.

Materials Handling in Farm Production, by Bill Butterworth, Published by Granada Publishing Ltd, May 1979, 175pp, paperback. £4.95.

JBH

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Minimum tillage of sugar cane in St Kitts

P T Jackson

Sugar cane and soil erosion

IN St Kitts the practice of burning cane prior to cutting (in general use for some four to five years in the late 60's and early 70's) had given rise to a severe decline in yields of cane. This trend was arrested and reversed with the formation in 1972 of SIRO (Sugar Industry Rescue Operation) when the policy of burning cane ceased. From that time onwards cane was cut green, the trash being re-spread over the field once the harvesting operation within the field was completed. NACO (National Agricultural Corporation) was established in 1975 as the successor to SIRO and continued to implement the green cane policy over the 12,400 acres "inherited" from SIRO.

However, it was apparent that when fields were replanted the cane trash remaining from the harvesting operation was causing difficulty in land preparation even when spread back over the field. While the trash could be virtually eliminated by burning, this was generally regarded as undesirable. The alternative was to incorporate the trash into the soil by the use of a Rome plough employing twelve 32 inch diameter discs. To prepare a field it proved necessary for three to five passes of the Rome plough to be made in order to obtain adequate incorporation of trash and satisfactory breakdown of the cane stools. Subsequent operations are dependent on whether the planting is to be carried out by hand or by machine. If by hand, then the soil is ridged or banked using a disc ridger. If a mechanical planter is to be used then a further harrowing may be given prior to planting with the primary objective of obtaining a reasonably level surface over which to operate the planter.

On a soil which, in virtually all the cane growing areas, is sandy loam this intensity of mechanical operation reduces the soil to little more than dust; crumb structure is completely destroyed to a depth of several inches. As the majority of replanting is timed to coincide with the main wet season when high intensity rainfall is to be expected, soil erosion can be dramatically severe as over 75% of the cane land exceeds slopes of eight per cent and much being steeper than slopes of 15%. Contour planting is, of course, a standard practice but other techniques were clearly needed.

Minimum tillage method under evaluation

In general sugar cane is a crop which gives the soil surface excellent protection against erosion; in fact under circumstances when the cane is harvested green, the only time when the soil is in a condition susceptible to erosion is when the crop is replanted.

After harvest the trash is spread evenly over the surface of the field before regrowth of the ratooning cane appears. This trash layer or blanket varies in depth from two to three inches to as much as 8 inch of loose material which fairly rapidly forms a more compact layer. The trash blanket forms an excellent protection for the soil against high intensity, moderate duration, highly erosive rainfall. It was all the more regrettable that the trash cover had to be destroyed, therefore, in order to replant a field. However neither a mechanical planter nor any form of furrower for hand planting could successfully penetrate the trash blanket. At best a bundle of trash built up in front of the machine after travelling some five or six yards, leading to frequent stoppages to clear planters or furrowers. Furthermore, the problem of destroying the old cane stools remained. The latter problem has been solved with introduction of the herbicide glyphosate, sold under the trade name "Round-up" which appears to produce a satisfactory "kill" of the old cane stools by spraying at a rate of three to four pints of concentrate per acre in 40 to 45 gallons water. This solution should be applied when the cane re-growth is roughly 1½ — 2 feet high.

In order to penetrate the trash blanket a machine was built which carried two 30 inch diameter discs fabricated from ¼ inch thick mild steel plate, bevelled to produce a cutting edge which was treated with an abrasion resistant alloy to reduce wear. The discs were each mounted on the front wheel hubs of a scrapped tractor in such a manner that some lateral swinging movement was possible (in the manner of the disc coulter on a mould-board plough). The frame of the implement was heavily ballasted with approximately 1500 lb of tractor front weights (jerrican type) in order to achieve satisfactory cutting of the trash blanket. In fact it was found desirable for the disc to penetrate up to 6 inch into the soil. The implement therefore produced two slots set (in this case) five feet apart, each slot being midway between the old cane rows (which were planted five feet apart).

After this slotting operation it was possible for either a cane planter or a furrower to follow the slot and open a furrow through the trash blanket into which the cane setts could be dropped. Preference is for mechanical planting since it leaves the remaining trash cover less disturbed and also conserves soil moisture by covering the setts with soil as they are dropped into the furrow.

Summary of operations

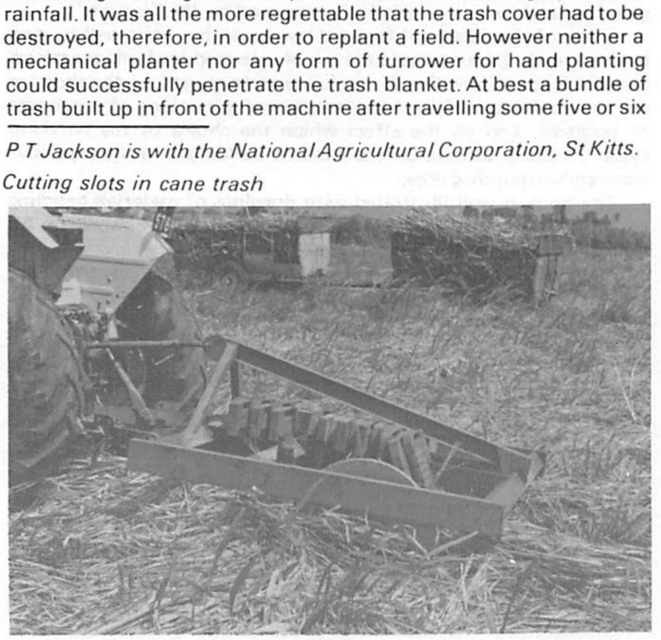
1. Spread trash after cane cutting completed (brush cut if necessary)
2. Wait 4-6 weeks for cane regrowth
3. Spray with glyphosate to kill regrowth
4. Cut slots using regrowth as steering guide
5. Plant.

Future developments

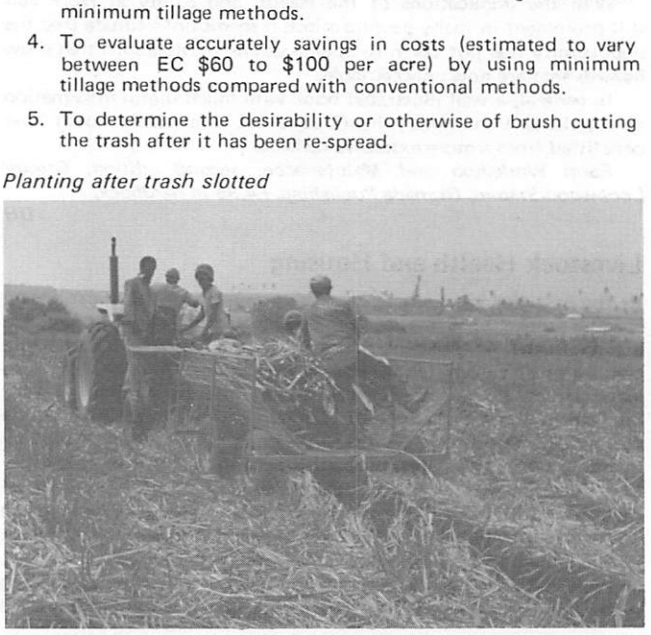
1. To mount the slot cutting-disc in front of the planter, thereby:—
   (a) reducing the number of passes across the field and
   (b) greatly simplifying the tractor operators task by not having to closely follow a narrow slot cut into the trash and which is sometimes difficult to see.
2. To mount a slotting disc in front of a disc ridger for hand planting.
3. To evaluate yields of plant and ratoon cane grown under minimum tillage methods.
4. To evaluate accurately savings in costs (estimated to vary between EC $60 to $100 per acre) by using minimum tillage methods compared with conventional methods.
5. To determine the desirability or otherwise of brush cutting the trash after it has been re-spread.

P T Jackson is with the National Agricultural Corporation, St Kitts.

Cutting slots in cane trash



Planting after trash slotted



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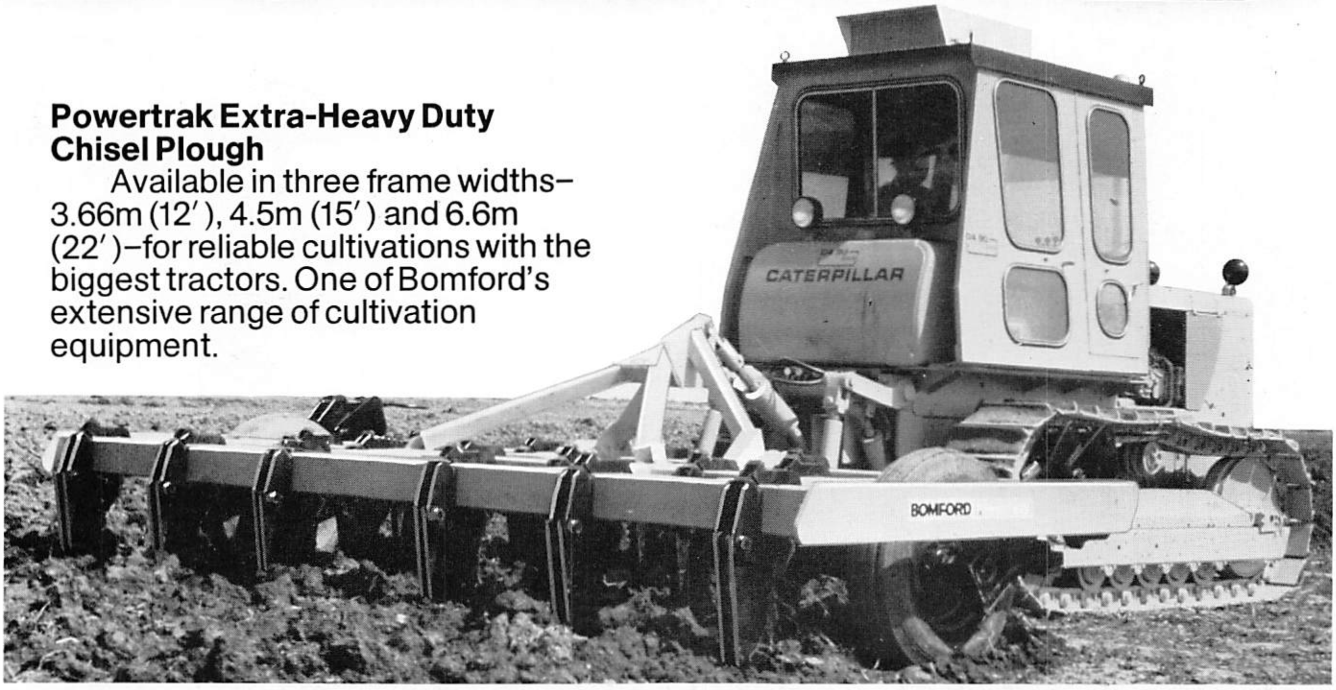

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