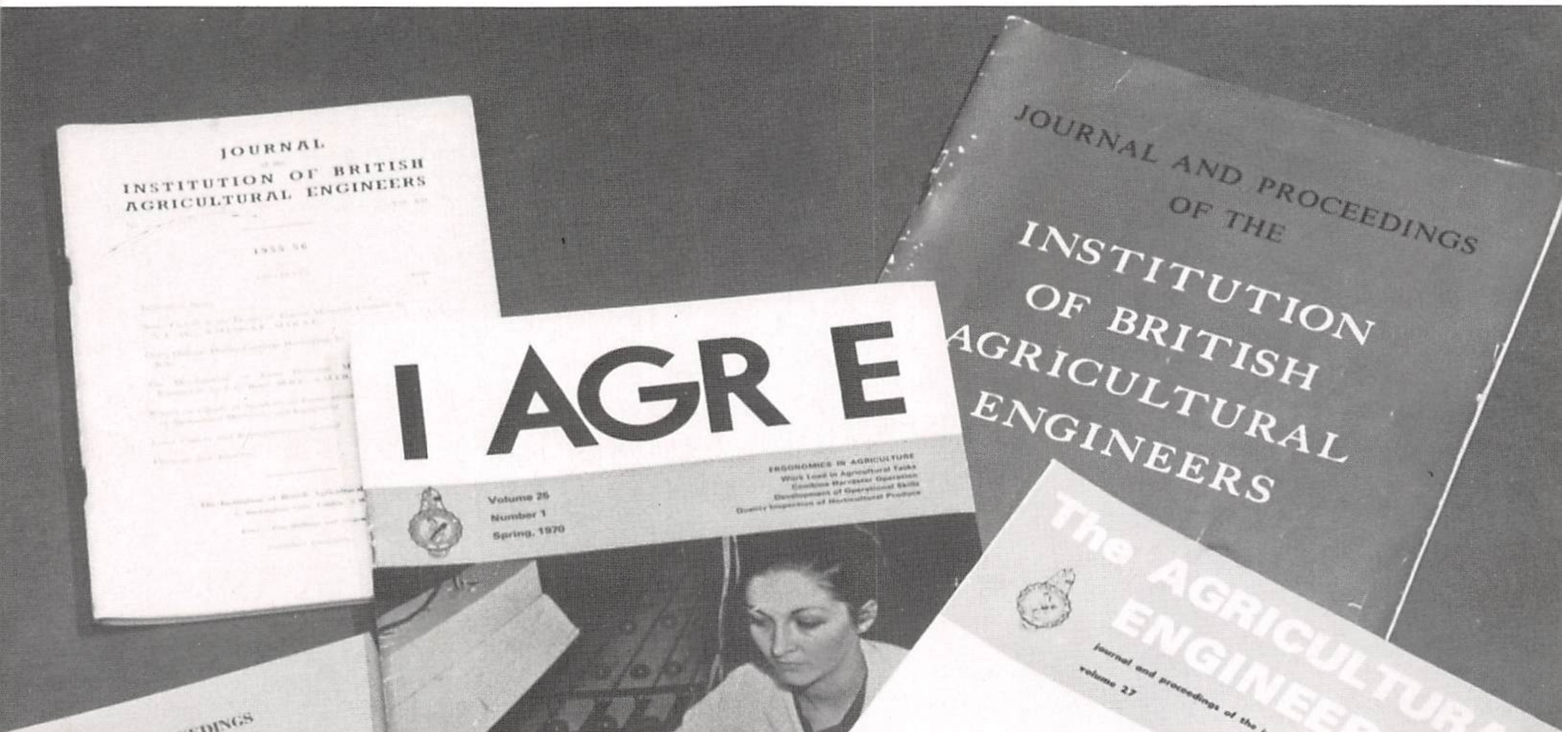
THE AGRICULTURAL ENGINEER

Volume 43 Number 3 AUTUMN 1988



Golden Jubilee 1938–1988
Review – Part I

The Institution of Agricultural Engineers

Journal and Proceedings

THE AGRICULTURAL ENGINEER is published quarterly
by the Institution of Agricultural Engineers
West End Road, Silsoe, Bedford MK45 4DU
Tel: 0525 61096

Price £6.00 per copy, annual subscription £23.00 (post free in UK)

Front cover:
Some covers of the Journal taken over the years since first published

THE AGRICULTURAL ENGINEER

Golden Jubilee 1938–88
Review — Part I

Volume 43 Number 3 AUTUMN 1988

Contents

ISSN 0308-5732

Presidential address
Challenge and change in Agricultural Engineering

B D Witney

Summary
THE success of the "World Machine" for food, fibre and renewable energy production has placed agriculture in transition. The attainment of commodity surpluses has coincided with a change in consumer trends and in public attitude to access to the countryside. There are changes within the land based industries which present Agricultural Engineers with a challenge to grasp new opportunities. The changes are both technological and social in character, and together they present an exciting prospect. Where land set-aside requires the availability of inexpensive implements, where crop diversification points to the adaptation of existing equipment and where efficient food production demands the development of fully automated machines, the skills of the engineer, combined with more effective machinery management, are crucial to the overall profitability of the farm business on which the commercial viability of the Agricultural Engineering Industry ultimately depends.

The UK has long been the World's largest exporter of agricultural tractors. These exports generate one of the country's biggest net trade balances. Within the smaller agricultural machinery sector of the industry, the greater uptake of innovation and more aggressive marketing are important. Young engineers can look to a demanding future actively exploiting the technological advances in electronics, robotics and machine vision. The Institution itself will continue to provide a technical forum and a professional home for its Agricultural Engineering members, and play an important part in their career development within tomorrow's agriculture worldwide.

1 Introduction
It is an honour and privilege to accept the Presidency of the Institution of Agricultural Engineers in this our Golden Jubilee year. During only a few decades, the labour-intensive drudgery of peasant agriculture has been transformed into a highly mechanised and automated process. It only takes a brief holiday in the eastern Mediterranean to remind us that the sickle is still as common a sight as the combine harvester but in fields of different sizes. The ingenuity of a few, now famous, farm machinery inventors provide markers on the road towards higher labour efficiency. Equally important, however, are the cumulative contributions of a host of researchers, manufacturers and educationalists promoting improvements in the design, production and utilisation of agricultural equipment. As members of the Agricultural Engineering profession, we must be justifiably proud of our involvement in these achievements. We also have a commitment to ensuring the future success of the "World Machine" for food, fibre and renewable energy production.

The very success of these past endeavours has created fresh challenges. Agriculture is in transition. Self-sufficiency in food production has coincided with a change in consumer trends and with a change in public attitude towards access to the countryside. There is more emphasis on a healthier lifestyle through diet and outdoor activities. This has enhanced the importance of conserving the rural environment within an agricultural framework. This does not diminish the need for the skilled use of agricultural equipment. Nor does it transform farmers into groundsmen for a nationwide countryside park.

President Brian Witney is Director of the Scottish Centre of Agricultural Engineering, East of Scotland College of Agriculture, Penicuik, Midlothian.

2 Challenge through success
The real challenge for all Agricultural Engineers is to collectively reaffirm a sense of pride in our chosen profession. We *can* produce inexpensive machines to meet the demands of a land set-aside policy. We *can* adapt existing equipment for crop diversification schemes. And we *can* develop and economically operate fully automatic machines for an efficient food production policy. Public opinion has shifted disastrously against

agriculture. It would seem that every farm has its private food mountain or milk lake which inevitably blocks a right of way. We are embroiled in farming's bad press on the current issues of straw burning, of hedgerow removal, of slurry odours and of agro-chemical residues. Seen in this light alone, there would be little justification for continued fiscal support for an agricultural industry of only 200,000 full-time farmers in the UK. This, of course, belies the fact that much of the state funding benefits the consumer rather than the producer.

The predicament facing agriculture is not lack of achievement. Rather, it is the total inadequacy of promoting its own image. This identity crisis is reflected in Agricultural Engineering. We have not projected our horizons vigorously enough to encompass all the land based industries within our global terminology. Instead, we have made cosmetic changes in semantics and paid homage to potential market opportunities in particular sectors, such as the precision machinery or food technology and the more diffuse engineering requirements for a changing rural environment. Change always creates a challenge, a challenge to grasp new opportunities within the technological and social infrastructure beyond the urban fringe.

3 Machinery management

The most immediate opportunity is to make the Agricultural Industry more competitive by reducing production costs and by increasing product quality. Over the past decade, production costs have increased more rapidly than farm output. This cost/price squeeze has led to a decline in farm profitability. Prices are unlikely to increase in real terms during a period of commodity surpluses. So, improvements in net farm income depend on reducing production costs. For management purposes, the costs of production are divided into overhead — or fixed — costs and variable costs which cover the outlay on seed, fertiliser and feed for specific enterprises. Although it is the variable costs which are rising, there is only modest scope for savings. Lower inputs reduce crop and animal production which, in turn, decrease farm output. For this reason, management emphasis is placed on containing fixed costs which represent about 40 per cent of the total financial outlay on arable enterprises.

The major fixed costs are labour, power and machinery, and interest on borrowed capital — *Men, Machines* and *Money*. The term "fixed costs" is a singularly unfortunate one because it implies that they cannot be altered. This is not so, but any change certainly involves drastic measures and can only be brought about slowly over a period of time. The largest fixed cost is for power and machinery, with depreciation accounting for about half of the item. Both repairs and fuel account for about a quarter each. Often, however, labour is considered jointly with machinery because of their interaction. One substitutes for the other, and together they represent about 65% of all fixed costs.

The increasing hourly rates for skilled operators continue to encourage the trend toward fewer, more powerful tractors and machines, with a consequential decline in the agricultural labour force. The most significant shift in recent buying behaviour is the transfer of over 20% of the annual tractor sales from the 31–60 kW power category to the 61–90 kW size. This market change makes the 61–90 kW power category the largest market sector. It now represents almost half of the annual tractor sales. The undercurrent of concern about soil damage is likely to discourage widespread use of very much heavier conventional equipment and favour the adoption of, for example, wide gantries which are already making a limited appearance, or novel wheel systems.

Whilst the average power of new tractors is still increasing, the number of licensed tractors has declined steadily from a peak in the mid-1960s. This means that the total tractor power has probably reached a plateau. Western Europe is now seen as a replacement machinery market. The process of *mechanisation* is virtually complete and is giving way to the process of *machinery management*. During the early stages of mechanisation, individual machines were introduced to save labour, to increase output, to improve product quality, and to reduce drudgery. These benefits were often so substantial that scant regard was given to full farm planning. Surplus power was seen as a positive advantage to accommodate expanding machinery capacity and diversity.

In contrast, however, mis-matched machinery systems now represent a major cost burden on fully mechanised farms. The wrong choice of machine can only be corrected by tying up more capital to advance the date of machine replacement. As the number, size, complexity, and cost of machines increase, the adequacy of machinery management has a major impact on farm profitability.

The more effective the machinery management strategy, the higher the profit it achieves for the farm business. This economic goal is not necessarily equivalent to minimising machinery costs for a number of reasons. It may well be the case that optimum use of equipment requires a change of area which does not fit into the crop rotation. Inadequate machine capacity may incur yield penalties from untimely operations, whereas overcapacity may introduce the risk of greater soil damage.

Whilst it is sound business practice to contain fixed costs, any savings must be achieved within the framework of a scheduled replacement policy. The intention is to achieve a uniform level of reinvestment in new machinery. There must not be undue fluctuations in capital demand from year to year, and all machines must be replaced over a reasonable timespan. The recent trend of extending the machinery ownership period is an indication not simply of hard times but rather of the substantial improvement in reliability over the last few years. Farmers quite rightly no longer tolerate paying for the privilege of field testing unproven machine designs. There is, however, no easy shortcut for manufacturers building a reputation for quality engineering. It takes extra time and cost which must be reflected in the product price and which relies heavily on the discerning customer to disregard cheap imitations.

4 Manufacturing base

The declining fortunes of agriculture during the past decade have adversely affected the commercial success of the UK Agricultural Engineering Industry. The severity of the downturn in machinery investment worldwide has caused many companies to restructure their operations through acquisition and amalgamation, as some of our members are painfully aware. There is now modest optimism of a recovery in machinery sales, first established in the dairy and livestock sectors. The total value of agricultural engineering products in 1987 was approximately £1.3 billion, of which just under three quarters was attributed to tractor sales and the remainder to agricultural machinery.

There are almost 1000 companies recorded in the census of production as Agricultural Engineers. Of these, some 90% employ less than ten people but, being located in rural areas, farm machinery manufacturers often represent a major local employer. At the end of 1987, over 23,000 people were employed in the manufacture of agricultural engineering products, and it is likely that as many again are involved in the importation, distribution and servicing of farm equipment.

The UK has long been the world's largest exporter of agricultural tractors, with an export ratio of over 80%. As one of the country's largest net trade earning industries, it has a positive trade balance of over £300 million, despite the depressed level of world markets.

Import penetration of the domestic market is high at around 56%, but this is due to the concentration of production of the "European" tractor in continental Europe and of the "World" tractor in the UK.

The smaller agricultural machinery sector exports over £160 million, but innovation and more aggressive marketing are necessary to improve our share of the domestic market. It is disappointing to find that there is a bigger financial return and less risk by importing foreign tackle than by developing and marketing British ideas. It is also unfortunate that once a novel machine concept, such as the big roll baler, really becomes established, the same manufacturing source is often used to expand the product range of several companies and there is little more than the colour of the paint to choose between them.

Of course, innovative research and development may be an expensive gamble for some of the smaller, undercapitalised companies. This is where partial government support through the Agricultural Machinery Partnership Scheme is so important in making core-funded research facilities available to individual companies for the confidential development and evaluation of pre-production prototypes. Despite the provision of this type of financial inducement, the UK Agricultural Engineering Industry is not renowned for its eagerness to exploit many of the novel machine concepts incorporated into experimental rigs at the state funded research and development establishments. When our *European* neighbours adopt *British* developments to improve *their* market share in *this* country, it is hardly surprising that the original research and development investment comes under scrutiny.

5 Technological opportunities

How do we, the researcher, the manufacturer, the adviser, and the farmer back a winner? Strategic research priorities are assessed against six criteria:

timeliness,
pervasiveness,
excellence,
exploitability,
applicability, and
educational significance.

No indication is given of the ranking order of these six criteria. This is perhaps advisable because the reasons which ultimately determine the market success frequently confound the original selection philosophy. Take, for example, the energy saving campaign in North East China. The objective was clear cut. By improving the thermal efficiency of cooking stoves, a larger proportion of organic waste could be used to enhance soil fertility. The new stove which was developed had a thermal efficiency of 35% compared with ten per cent for the old one — excellent engineering. Its adoption exceeded all expectations. In under three years, the uptake of the new stove by around 90% of the nine million families saved an estimated 5.5 million tonnes of straw per year. The anticipated improvements in crop production were achieved. The reason for the "pervasiveness" of the technology was, however, a completely unexpected form of "timeliness". On the new kitchen range, the water for the tea could be boiled while the rice was cooked, rather than sequentially as in the past. It was the immediacy of the social benefit which guaranteed the adoption of the new technology, not the governmental research priority for agriculture. This encapsulates a topical comment by Lord Sanderson, who said, "Near Market Research is as hard to define as Organic Farming."

Returning to Western technology, the tractor cab fulfils a similar social role to the cooking stove. Tractor designers are well aware of the importance of operator comfort in attaining higher productivity. In the factory production lines, cab assembly procedures are now more complex and time consuming than those for the power train and integral chassis. The safety cab and rudimentary instrumentation of only a few years ago is being transformed rapidly into an independently sprung, operator capsule. This operator capsule is fully equipped with expert systems which automatically optimise machine performance within the prescribed limits of dynamic stability and ground mobility.

Robotics are being applied to provide automatic milking of dairy cattle. There are also major advances in machine vision technology. Once the spectral discrimination of machine vision is as good as its spatial discrimination, there will be numerous applications for the technology in produce handling, inspection and quality control. The pace of innovation in electronics is now so fast that these developments inevitably inspire the imagination — and so they should. Nevertheless, the real scope is not for optional electronic extras. It is for the integrated engineering design of proven mechanical, hydraulic and electronic systems. The reliability of electronic control circuitry is seldom in doubt, whereas it is much harder to find robust transducers which can cope for prolonged periods with either the climatic extremes and abrasive soils in field operations, or the rugged environmental conditions in intensive livestock buildings.

6 Professionalism

This Golden Jubilee Celebration does not in itself justify the survival of our Institution. There are always the critical who consider that all official bodies gradually become anachronistic and moribund. Let me quote from *Young's Travels in France in 1789.* "There is here a Society of Agriculture... This society does like other societies — they meet, converse, offer premiums and publish nonsense. This is not of much consequence; for the people, instead of reading their memoirs, are not able to read at all." Let us dispel that image.

The primary purpose of the Institution of Agricultural Engineers is to provide a technical forum and a professional home for its membership. The Institution is small. This means that a relatively few dedicated members, ably assisted by an efficient Secretariat, strive to fulfil that primary purpose. We must endeavour to strengthen our future through growth, growth not only in professional stature but also in membership. The two are inseparable. And it is difficult to decide whether higher professional standards encourage membership or whether a larger membership improves professional standards.

Perhaps the most important part of our professionalism is "manpower quality control" or engineering registration to use its proper title. In 1985, the Affiliation of the Institution of Agricultural Engineers to the Institution of Civil Engineers which holds a Royal Charter enabled us to process members' applications for registration as Chartered Engineers (CEng). Engineering Council further conferred the right on our Institution to approve the registration of Technician Engineers and Engineering Technicians (TEng and EngTech). In an attempt to reduce the confusion between these two sections of the register in the public's mind, it was announced recently by Engineering Council that the intermediate section of register would be known as Incorporated Engineers (IEng). A total of approximately 60,000 Technician Engineers will shortly transfer to the new title of Incorporated Engineer which more suitably describes their professional capabilities. The next phase of engineering registration, recently announced, goes beyond national boundaries to identify European Engineers.

As well as growth in professionalism, there is recruitment to membership. The present Branch network has been very effective in allowing technical progress to be disseminated at evening talks and at conferences. As attendance is seldom restricted, local participants often see little justification for membership. There are, however, many members — and some visitors — who seek a greater technological participation in their chosen fields. Following the successful establishment of a Specialist Group in Crop Drying and Storage, others have been inaugurated in Machinery Management, in Electronics and in Livestock Engineering. These Specialist Groups are located in different parts of the country and introduce a further social dimension of mixing members from different Branches. The Groups encourage a corporate spirit and provide a tangible benefit for recruitment. The Specialist Group concept also introduces the necessary flexibility for other land based industries to join us, yet retain their own identity, for example in Forestry Engineering. And there may be others in Farm Buildings, in Irrigation, and in Food Technology who may well wish to contribute to and benefit from the broader base of a composite professional organisation. Even the Young Engineers Section, launched last year through the personal involvement of the Immediate Past President, represents a different form of special interest group, age-based rather than commodity-based. These developments, together with the emphasis placed on Continued Education and Training, demonstrate our commitment to growth in all aspects of membership and our confidence in the career prospects within the Industry as a whole.

7 Manpower changes

Future manpower in Agricultural Engineering will require a range of specialist abilities, for example in Chemical Engineering, Electronic Engineering, Information Engineering. There is, however, a move away from the so-called "T shaped" engineers who gain management positions from a narrow specialist base. Instead, there is an educational rquirement for a broad-based degree, followed by alternate periods of specialism in emerging technologies and generalisation, as engineers move through their career paths towards higher management. There is also a need for greater appreciation of agriculture on a European basis, and for a period of training and experience in tropical or developing countries.

More importance is now attached to public relations, economic awareness, marketing and commercialism. We must all be able to sell our skills in the market place and, by providing the solution to one problem, lay the foundation for further business.

8 Market outlook

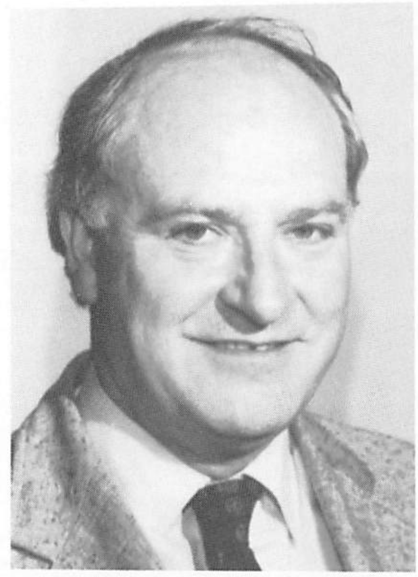
What is the ultimate accolade of success for the Agricultural Engineer? We must be able to advance the mutual prosperity of the manufacturer and machinery user through consumer satisfaction with a regular and adequate supply of food. Unless you believe that the world will regress to subsistence agriculture, I can summarise my Address in seven words:

No farm machines, *No* food, *No* future.

Let us ensure that we are *Positive* in our response to this challenge.

Technology and Agricultural Engineering — A personal view

J R O'Callaghan



Summary

IN a brief review of agricultural engineering, the processes of development during the past half-century have been partly in response to social factors in the general economy outside agriculture, and partly the result of technological innovations from within agricultural engineering. The results of that development mainly took the form of 'hardware'. In the future social factors will continue to dominate the development of agriculture with the strong possibility that the industry may be divided between 'high-tech' and 'low-tech' farmers. Technological development will be influenced by ecological conservation, biotechnology and information technology and as a result 'software' will be an important factor both in its own right and as a strong influence on machinery development.

1 Introduction

To convey a sense of perspective on agricultural engineering during the past half-century, I can just remember farming in 1938, or more correctly, the general impression of that time sharpened by the benefit of hindsight. One was aware that land was practically unsaleable, that prices were unbearably low, and that the whole operation, including existence itself, was by courtesy of the bank manager. 'Cash-flow' was not part of my vocabulary, but I knew exactly what the concept meant from a very early age. Precarious may have been the life of the farmer and his family but it was bliss by comparison with that of the farm labourer and his family, because farming in the thirties was totally dependent on casual labour, with peaks of employment at sowing in the spring and at harvest in the autumn. Many of the children I played with were the sons and daughters of farm labourers, and I can still recall, with horror, the deprivations of unemployment for them and their parents during the long winter months, and the burden for all of them, which was their grandfathers, who were no longer fit enough to be employed for more than a week or two at harvest time.

Jim O'Callagan is Professor of Agricultural Engineering at the University of Newcastle-upon-Tyne.

For me, the most exciting development, during the past half-century, has been mechanisation. For the first time in history, farmers were able to flatten the peaks of labour demand at sowing and harvest with the help of machinery, and there was the possibility of full and rewarding employment for those engaged in agriculture. Industrialization took care of those displaced from the countryside, while guaranteed prices and full demand financed change, and gave confidence to those who stayed behind.

2 The agricultural industry

The food shortages of the war, and the immediate post-war period created a climate of demand for everything that farmers could produce. Sustained demand was able to absorb increased output at levels of profit, which supported technical innovation. There were spectacular improvements in the productivity of the labour in farming, as the pool of casual labour was attracted into urban industry. The demand for labour in the total economy was so great that the agricultural sector was able to, what we now call, 'restructure', not only without pain but with excitement.

Since the War, the labour force in agriculture has fallen by two-thirds, while the number of farms has more than halved. However farms have increased in size and become more specialised. Gross output has increased steadily since the War, but so also have the purchased inputs. The gross product of the industry (the difference between gross output and gross input) has grown considerably in cash terms, but when allowance is made for inflation, the real purchasing power of the total incomes earned in agriculture has shown a downward trend since 1946. This fact appears to contradict experience, but the reason for the prosperity during this period is that the total has been shared by a smaller number of farmers and farm-workers. There has been a dramatic increase in the share of real gross product going to the repayment of capital, depreciation and interest charges, which have risen from 16% of the total gross product of the Industry in 1972 to 33% in 1984. The hired labour and family labour shares have remained relatively constant at about 25 and 10% respectively. The residual farming income, which is the return to the farmers' own labour, management and capital assets, has fallen from nearly half to a third.

The story that these figures tell, according to my colleague David

Harvey, Professor of Agricultural Economics, is that

"the economic productivity of the industry has tended to fall in spite of the rapid improvement in the physical productivity of the industry, especially in crop and dairy cow yields. The economic returns to be earned in agriculture, particularly by labour, have not kept pace with the physical output produced by the industry, and have not been sufficient to persuade people to stay in the industry. The returns earned by capital investment in the industry however encouraged additional investment. Much of this encouragement has come from the tax treatment of incomes and wealth in the industry, and from capital grants and subsidies paid for improvements. In addition, the favourable expectations about the profitability of agriculture, associated with government policies and statements and also with world market conditions, especially in the early 70s, encouraged investment at that time. The actual profits earned since then have not lived up to these expectations and the industry has increased its borrowings substantially in order to maintain net incomes and to pay interest charges on earlier borrowings. This response is not sustainable in the longer term, and the industry has been running down its capital stock for the last 5 or 6 years, by not replacing plant and equipment so frequently."

3 Agricultural mechanisation

In my paper to the Institution's Jubilee Conference, I divided post-war mechanisation into four phases:—

- (i) the decade immediately after World War II, when the foundations of the present system of farm mechanisation were laid, with their emphasis on high agricultural productivity, and the replacement of manual labour by machines;
- (ii) a period of great technological advance in the late fifties and sixties, when better design of tractors and machines and especially of diesel engines, and the use of hydraulics, all raised machine productivity. These developments made it almost impossible for the older equipment to compete with the new machines so that technical obsolescence was the major factor in replacement;
- (iii) high monetary inflation in the seventies, with guaranteed prices and negative real interest rates, produced conditions very favourable for the replacement of existing machines by new and bigger models;
- (iv) during the eighties, the outlook for farming in the EC has changed, from one of expectation of continuous trouble-free expansion with guaranteed prices to one of over-supply, falling prices and a mature machinery industry, in which farmers approach the replacement of machinery in a cautious mood.

Looking at the half century in this way, technical advance has not been as great a driving force in the industry as might be expected. The first phase was a response to the needs of farmers to meet a shortage of labour. In many cases it was little more than the replacement of horses by more powerful mechanical traction. With hindsight, it is remarkable how slow the industry has been in raising the engine power to meet a demand that was there from the beginning. The principal period of technological advance was during the second phase when the diesel engine was adopted universally with a better range of gears, mounted implements, and pto and hydraulic transmission of power. The forage harvester appeared at this time but draught control, the combine and the baler all existed from before the war.

As impressive as the changes in design, although not as obvious, have been the improvements in the life and reliability of tractors and machines through the use of better materials and quality control. To be successful in a mature industry such as ours, research and development are necessary in order to produce incremental improvements in performance and remain competitive. At a time when farmers are replacing their plant and equipment less frequently, there is pressure on firms to reduce research and development, a policy which is not without risks for their business prospects.

The capacity of the agricultural engineering industry to respond to the needs of a particular time with appropriate technology is as important as innovation. That high inflation could be an opportunity for the industry to increase sales and for farmers to want bigger tractors and machines was not foreseen.

However if one is to summarise the technical developments of the agricultural machinery industry during the past half century they are predominantly mechanical in nature and centered round the internal combustion engine. The technical achievements of the agricultural industry have been to raise yields of crops and livestock with the help of fertilizers and the products of the petrochemical industry. One thing that is certain during the next half century is the decline in the supply of oil and with it a big change in the practice of agriculture.

4 New technologies

4.1 Influences on technology type

The three major influences likely to determine the progress of agriculture during the next half century are environmental conservation, biotechnology and information technology, and it is possible to discern the trend of each of these developments at the present time. One possible outcome is that the industry might separate into high-tech and low-tech farms, which serve quite different needs.

Environmental conservation is about maintaining stable ecological systems. Underlying every system is its source of energy which for agriculture, until very recently, was solar energy. Agricultural productivity in the postwar period has been very dependent on nitrogen fertilizer, which exploits a transitory abundance of cheap oil. Excessive use of nitrogen fertiliser has led to leakage of nitrates into rivers and ground water. Similar imbalances have resulted from imports of feedstuffs for large-scale livestock units, which are not in balance with the area of land around them for the disposal of slurry. The widespread concern for the environment is a plea to farmers as well as to industrialists not to overload the capacity of soil, air and water systems to recycle the waste from their production operations. Gradually we have come to realise how fragile the environment is, and how wasteful we have been in using scarce resources.

Molecular biology is likely to produce the kind of improvements in natural production processes in the next century, which chemistry and physics did for industrial processes based on our reserves of metals and hydrocarbons, in this century. The major difference is that biological production processes ultimately depend on solar energy and are renewable, whereas the reserves of metals and hydrocarbons are finite. Genetic engineering has the possibilities for improving the performance of plants to fix their own nitrogen, to have better resistance to disease, and to produce more of the end product we require, and all by using solar energy.

Many extravagant claims have been made for information technology, but its greatest effect probably lies in its capacity to select, process and distribute information that is specific to a particular problem. No longer need the transfer of expert knowledge be through a human chain. As a result, knowledge-based activities can be distributed spatially through regional, national and global networks, so that many more people can interact with their colleagues and customers while working from home. A farmer can link his production processes directly to the best information and optimization algorithms that are available, without the need for intermediary advisers.

4.2 High-tech/Low-tech

Bringing the three strands together, of environmental conservation, biotechnology and information technology, is the basis of the proposition for the emergence of two broad categories of farming, especially in the present context of over-production. In the short-term the effects of information technology on the service industries are likely to have the most immediate effect on agriculture. Computerisation of office work is accelerating early retirement. Many of those who are taking early retirement are selling their houses in commuterland and moving into the country. As the pressure on agricultural prices tightens, more marginal farmers will become part-time farmers. It is possible also to detect the emergence of a new class of office workers, who need only attend the office occasionally, and who can work at home in a situation where their low overhead support costs are very attractive to their employers. Where such people live on farms, they are more likely to regard the land for its amenity value than as a source of production, and their farming will be of the low input-low output kind which is very acceptable ecologically.

For those in whole-time farming, the situation is going to get more competitive, as the prices for their products fall in order to get a better balance between supply and demand. In order to remain viable in this fiercely competitive environment, a farmer will need to use every aid available to him in order to reduce costs and increase added value. Farmers will need to maintain much tighter control over the production process than is normal at the present time for three reasons:—

(i) to control their production costs by making better use of inputs;
(ii) to farm within more tightly drawn environmental constraints than are in operation now;
(iii) to exercise quality control on their products, because the market will be sophisticated in its requirements and will relate price to specification.

The farmer will look to biotechnology to produce new strains to meet the specification of the markets and to produce plants and animals that are capable of carrying out more of the processing biologically of replacements for some of the present products of the petrochemical industry. It may take a long time to sort out our ideas for replacement products, but the agro-industrial market is essential for the future of agriculture, as a way of taking up the slack in demand in the traditional food market.

Information technology however seems to offer the best prospects to the farmer in meeting the costs-prices squeeze. Most farmers use broad prescriptions in selecting methods of cultivation, rates of application of fertilizer and range of sprays as well as in the timing of critical operations. With the use of expert systems, the quality of advice available to the farmers would be greatly enhanced. By interacting with a 'user-friendly' computer-based system, the farmer should improve his understanding of the growth processes and the way in which they react to different inputs. As a result the management of the whole operation should become more precise, better controlled, and lead to better conservation practice. An expert system supported by an array of suitable sensors that report the micro-environment of the field, or in the case of livestock, indices of animal performance and environmental factors, could propose alternatives for action to the farmer. In fact much of this is already happening in dairying and in the glasshouse industry.

5 Development of agricultural machinery

The emergence of two distinct categories of farming would have big implications for the agricultural machinery industry. The low input-low output farms are likely to be small and to require simple multi-purpose machinery, which is easy to operate and is not demanding in maintenance. The high-tech farmers will move towards greater precision in every stage of the production process so they will be even more concerned about machine performance than they are now. On the other hand, the scale of operations and the degree of specialisation among the high-tech producers may mean a greater willingness to invest in appropriate equipment. Possible areas for development are given below:

5.1 A re-examination of the equipment needed for cultivation and the preparation of seed-beds. The case for the re-examination is made on two grounds. Firstly, the costs and energy incurred in cultivation are a high part of crop production inputs and should be reduced. More importantly however is the need to resolve the soil compaction debate. Much research has shown the deleterious effects of wheel-loads on soil and crop yield, yet wheel loads have continued to grow.

5.2 Improve the application performance of sprayers. There is still an unacceptable gap between the precision with which sprays are formulated chemically and the random way droplets are produced and applied by sprayers in the field. Although improvements in plant resistance to disease through genetic engineering should reduce the need for spraying, it is very unlikely that we can dispense with it entirely.

5.3 Separation of the final product into a wide range of fractions to meet specific market-needs, together with post-harvest treatments to maintain the quality of the final product until it reaches the consumer. The food processing industry has become very inventive in developing new ways of marketing a wide range of foods. In their search to improve quality, presentation and specification they are likely to demand a more consistent raw material from the producer.

5.4 The integration of agricultural machinery into the information technology network raises problems at several levels. At its most basic, there is the question of standardisation, which would allow different types of equipment to be interfaced, and this problem is being examined. At another level there is the question of how agricultural machinery can be used to collect information that is useful to the information network as the machine moves through the field on its main function. For example, measuring grain yield at the point of harvesting and locating that yield spatially in the field would serve as a biological indicator of the distribution of yield throughout the field. Such information suitably processed to be readily available to the farmer would be a better diagnostic tool than, for example, soil analysis which draws conclusions from a small number of point samples. At yet another level there is the possibility of transferring information, which has been stored on computer from such other event, to the machine in order to control it, as for example using the yield data from the previous harvest to control a fertiliser application.

5.5 The production of agro-industrial raw materials raises a whole range of new problems in processing those materials, and especially about the appropriate scale for near-farm concentration as an intermediate processing stage between the farm and the industrial user.

6 Conclusions

The next half-century appears just as challenging and exciting as was the last half-century for agricultural engineering. The agricultural industry responds as strongly to social factors as it does to technology. In the past half-century agricultural mechanisation was as much a response to labour leaving the industry as it was the result of technical innovation. However, that period was dominated by petrochemical and mechanical technology which was characterised by 'hardware'. In the future we may have to recognise 'low-tech' farmers as a distinct group with special needs, as well as 'high-tech' farmers who will draw on resources of biotechnology and information technology but farm with precision within the constraints of environmental conservation. 'Software' will be important in its own right, as well as being an integral part of machinery development.

Fig 1 High-tec progress – the Pattenden raspberry harvester developed at SIAE

Changes in commercial and technological practices by large multinational corporations

D M Walker

ALTHOUGH the origins of the Agricultural Engineering Industry can be traced back over 150 years, Deere & Company for example began business in North America in 1837 with the manufacture of single furrow horse drawn ploughs, it is really only in the last fifty years or so that rapid strides have been made in technological practice. Pull-type combines for instance were seen in this country as far back as 1927, they operated entirely satisfactorily but were very heavy and clumsy and had to be pulled by a tractor fitted with a power take-off. There were few tractors with the necessary capacity available at that time with exception of a few crawler tractors which themselves were rather large and heavy due to the method of construction. This typified the technological position of machinery in those days. It was large, it was heavy; generally manufactured from castings and whilst these clumsy machines perhaps made life easier for the operator, they were by today's standards relatively inefficient.

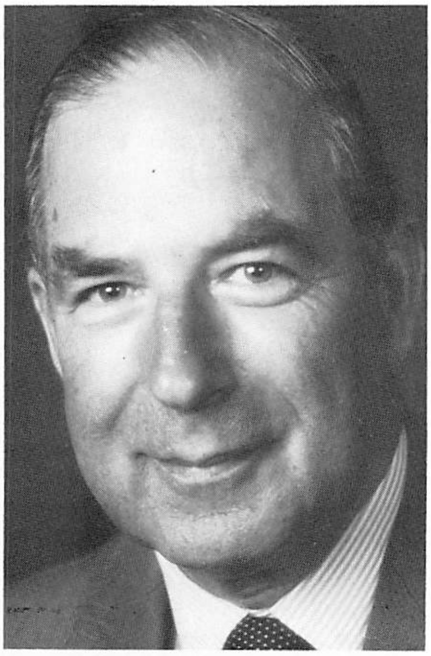
Improvements in design could be seen developing and evolving when probably the biggest breakthrough came with the Ferguson tractor in the late 1930s. These tractors had a high power to weight ratio, were of frameless construction and the most revolutionary feature being the hydraulic lift which allowed weight transfer to take place, giving improved traction.

As a result of the outbreak of War in 1939, there was virtually no development of agricultural tractors and machinery until sometime after the end of hostilities in 1945. Manufacture was based more on materials and component availability rather than new design.

From that time onwards the structure of farming began to change (table 1), with the number of farms decreasing by 280,000 and employees by 618,300. Average farm size increased substantially.

Around 1950, materials started to become progressively easier and technological change really started to take-off. In the early 1950s we saw the advent of the high speed diesel engine which very quickly superseded the petrol engine because of its better fuel consumption and lower running costs. Also the torque characteristics of diesel engines tended to suit farming practices better than petrol. Whilst in Europe in general, the diesel engine took over very quickly, this was not true in North America until the early 1970s. This was due to the low cost of petrol in the North American market. Even during this time the tractor was still a relatively basic unit as indeed were most of the other machines on the farm with the exception of combine harvesters where the first self-propelled combines were beginning to appear.

During the time under review we started to see some major structural



changes in the machinery industry. Like so many other industries in different fields of activities, it was quickly becoming clear that the smaller manufacturer was finding it increasingly difficult to compete with the large more efficient company. It also became evident in the minds of many corporate executives than a broad product line would be of great assistance in ensuring that the dealer

Table 1 Farming changes

Year	1950	1960	1970	1980	1987
Number of holdings x	533853	478160	328652	268760	254300
Average size of farm *	27.36	30.68	54.77	65.14	68.56
Average size of farm +				116.23	106.00
Number of employees	918000	693000	430000	328200	299700

(Source AEA)

x *Methods of reporting were changed in 1973 and 1980*
* *Figures calculated by dividing total agricultural area by number of holdings*
\+ *Figures from Annual Review of Agriculture*

Douglas Walker is Managing Director of John Deere Ltd, and President Elect of the Institution.

organisation was as exclusive as possible thus being in a position, theoretically at least, to provide a better product line and support to their present and future customers. The best example of this was the merger of Harry Ferguson of the UK and Massey Harris of Canada, the one being strong in tractors and the other being strong in farm machinery. The resultant company Massey Ferguson therefore became a major contender in the market place with a comprehensive product line. We have seen Deutz of Germany unite with Allis Chalmers of North America to give Deutz an access to the North American market through an established dealer organisation and more recently, we have seen Sperry Rand dispose of their farm machinery subsidiary Sperry New Holland to Ford Motor Company, thus creating another long line manufacturer.

It can be seen from the foregoing examples that this relatively recent process is unlikely to be complete as one can see obvious examples of other companies which are highly specialised in machinery or specialised in tractors where a union would presumably have mutual benefits for all involved.

There are two major exceptions to the general course of events that have been and indeed still are taking place in that John Deere in the early 50s purchased Lanz in Germany to provide a European base on which to expand in the overseas market which traditionally Deere had not undertaken in the past. This relatively quickly saw the demise of the Lanz tractor and other machines which were replaced by the more up to date John Deere designed line of tractors and machines. More recently we have seen the merger between Case and International Harvester whereby Case took over the financially troubled International Harvester company and has progressively discontinued many of the old Case machines. The reasons for these commercial mergers have been very varied but all of them have the same logical approach and that is to create a strong product base for expansion of business through a large comprehensive Dealer Organisation. One of the essential by-products of these mergers and takeovers is the inevitable reduction in the number of manufacturing units within any one company. It seems that there is no longer any place for duplicate manufacturing facilities but is rather toward fewer but more efficient facilities with state of the art technology allowing maximum flexibility through cellular manufacture, the use of robots where appropriate and "just in time" concept from component suppliers. Whilst all this manufacturing flexibility allows the model mix to be varied according to market demand this can only be successful if sufficient notice is given not only to the factory but also to suppliers to enable them to produce the necessary components as required. Forecasting requirements from factories will need to be a more exact science in the future as large stocks of machines cannot be held on the off-chance that a sale may materialise at some future date. To put this in context is quite simple. Ten tractors stocked for one year is equal to the cost of one unit which effectively means giving away free one tractor in ten.

This change is creating two new situations which one might say is the modular manufacturing approach where a basic unit can be relatively quickly altered to meet the requirements of any specific customer. A good and simple example of this being the installation of a 3, 4 or 6 cylinder engine into the same basic tractor structure thus keeping the commonality of design to the maximum extent possible. Another example is the commonality of straw walkers on combines with the basic walker being fitted across a range of combines.

Secondly, commonality of component is becoming increasingly important as this reduces parts stocking levels, makes for greater manufacturing flexibility and can provide for much easier servicing. Possibly the best example of this would be the interchange of corn heads which would either fit the front of a combine or the front of a self-propelled forage harvester. It is also possible that, due to the different harvesting times in the season, one header would be adequate for use by a farmer who had the base unit combine and base unit self-propelled forage harvester.

In the area of product within the multinational corporation, we are seeing many changes taking place which are often never noticed or if they are noticed are usually not considered to be a problem. If one looks at the multinational corporations today and compares their product line with that of a few years ago, there is sufficient evidence to show that the range of product is being slimmed down so that the factories within the group are producing the more sophisticated machines and getting out of the more basic farm equipment such as ploughs, cultivators etc. These implements are being left to the local supplier who generally does not market on a very wide base, since the cost of shipping and supporting these products to distant parts is usually too expensive for the multinational company to compete with the smaller local manufacturer. On the other hand the investment required for sophisticated machines has continued to grow as the demands of the customer has changed.

Earlier, the size of farm was discussed but we should not ignore the changes in farming practice which also has made an impact. The surprising change is the substantial increase in arable hectares by some 30% but permanent grass hardly changed whereas arable grass has declined by some 45% (table 2). Therefore it is obvious that larger farms, greater acreages and fewer farm workers has had a major impact on machinery development which can be seen by changes in machinery demand. Tractors are the best example as the statistics are available on a reliable base (table 3). The fluctuations in tractor registrations over the period can be seen but the underlying unit trend is down which is hardly surprising but horse power has gone up consistently and is

Table 2 Crop changes (area in hectares x 10^3)

Year	1950	1960	1970	1980	1987
Cereal crops	2937	3106	3714	3938	3940
Temporary grass	2738	2747	2308	1965	1699
Permanent grass	5309	5186	4946	5140	5108

Table 3 Tractor and combine changes

Year	1950	1960	1970	1980	1987
Tractor registration #	27490	29980	33835	21243	19689
Tractor total hp #	962150	1409060	1911678	1559236	1638125
Tractors in use	313992	437340	469896	514295	N/A
Combine registrations	N/A	N/A	2332	2081	1443
Combines in use	10120	52360	56670	57487	42468
Licensed combines in use	—	—	—	44401	42468

\# *Estimated figures*
N/A *Figures are not reliable as not specifically broken out (source AEA)*

around 90% greater in 1987 compared with 1950. It will also be noticed that the number of tractor units on the farm has increased which means that many tractors are probably old and unlikely to be used much as one man to two tractors seems highly improbable (table 1).

Not only has the demand from the customer changed but the legal requirements are also having a major impact. An example of this is the introduction of the safety cab a few years ago to meet the requirements of protecting an operator from injury. These early cabs were very basic, were noisy and did not create a pleasant working environment although they did give excellent weather protection. There was resistance of course from customers to the fitting of a cab, then gradually the demand changed where the customer accepted the cab but required greater comfort. The first to produce such a cab was John Deere with the "Sound Gard Body" back in the early 1970s and initially available on tractors over 100 hp. These cabs for the first time were integral parts of the tractor and included the instrumentation, steering wheel, instruments, seat etc. with a padded interior. air conditioning, radio etc and they set the norm from which today's cabs have evolved.

It is also interesting to note that the early cabs were manufactured by specialists in that field whereas today most tractor manufacturers now produce their own cab to meet their own specific requirement. From sound levels way in excess of 90 dB(A) down to below 80 dB(A) and shortly I suspect to 75 db(A), the operator today has an outstanding working environment which of course is also true on other self-propelled machines such as combines and forage harvesters. The operator has come to expect these and will in general accept nothing less. Of course the fitting of these cabs has brought in new technologies to agriculture with the use of plastics, sophisticated seating arrangements, air conditioning, electronics, etc.

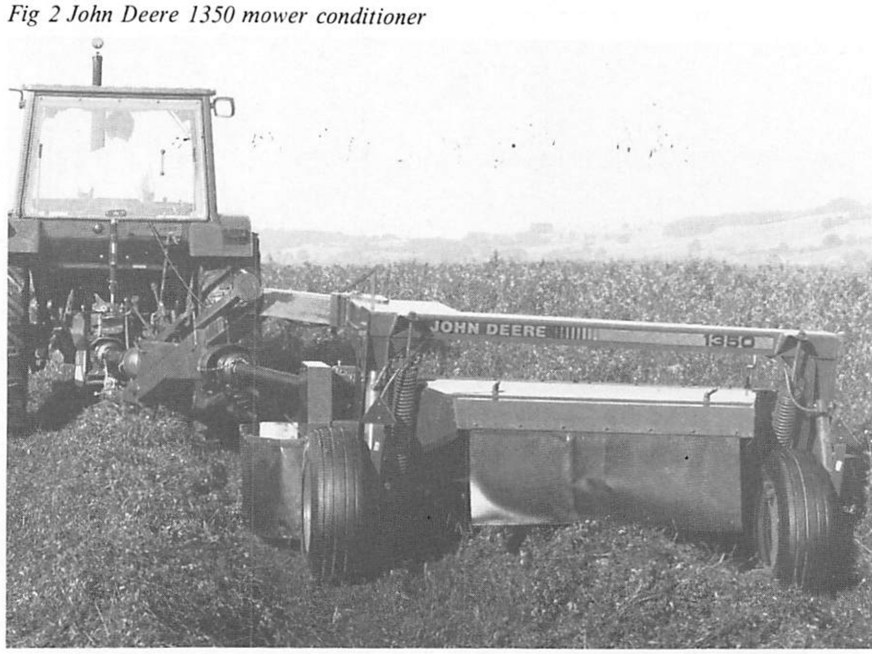
With the reduction in demand for farm machinery there has been a significant contraction in the number of dealers. Today's dealer has to cover a larger area in order to have sufficient market potential to allow him to survive. This implies that a full line manufacturer will require perhaps 130–150 dealers to cover the UK adequately.

Today's dealer has to be technically competent, provide fast efficient service, good parts support and be available on call 24 hours a day and seven days a week during seasonal farming activities.

With fewer and bigger machines on the farm it is self-evident that the farmer is so dependent on his machines that back-up support is now a top requirement demanded by the farmer from his dealer. To ensure

Fig 1 John Deere 1950 tractor

Fig 2 John Deere 1350 mower conditioner



that this support is properly provided, the large manufacturer now has to provide sophisticated training in service, sales, product knowledge, accounting, management etc. This training is now readily accepted as essential if the customer is to be satisfied with today's sophisticated machines.

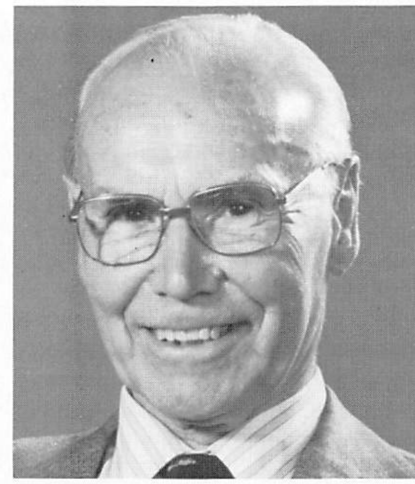
A recent change is the development of high technology Parts supports centres. These computer controlled warehouses are designed to be highly efficient and to provide speedy service to all parts of the world. The latest development in our industry is the installation of computer terminals at dealer's place of business which are linked to the major manufacturer's computer. This will dramatically improve communications, provide information and allow speedy accurate decisions.

All of these changes which have occurred and those which will appear in the future are aimed at providing products which can be built to provide cost effective investment yet can be easily adapted to meet the requirements of different markets with fast, efficient support to ensure minimum downtime.

But these developments, costing significant sums of money, can only be borne by the large multinational corporation which can support the infrastructure. To ensure that these changes are implemented effectively the smaller companies will have to seek a union with another firm whose products are complementary. I believe that there are perhaps two or at most three, potential unions left where the new joint company will have the resources to compete on a worldwide base with the multinational corporations already established.

Fifty years of Mechanisation Advisory Work

C Culpin, P L Redman and J G Shiach

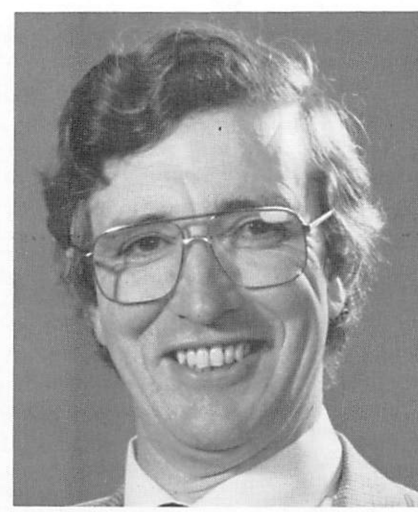


C Culpin

Summary

THIS paper traces the development of mechanisation advice in England and Wales and in Scotland from its inception as a contribution to sustaining food production during war time through to the commercial approach of today. Although the Advisory Service has developed along different lines in Scotland, many aspects are common. Changes in the organisation and in the methods of working of the Advisory Services reflected the changing patterns within the industry as a whole. Originally the objective for the then Machinery Instructors was to improve the operation of machines on farms. Following the formation of the Advisory Services by the 1944 Act, Mechanisation Advisers moved to work at a higher technical level aimed at developing improvements in the performance of machines and systems of mechanisation, working in close co-operation with the Engineering Research Institutes throughout. The contribution of field studies of machine performance is highlighted.

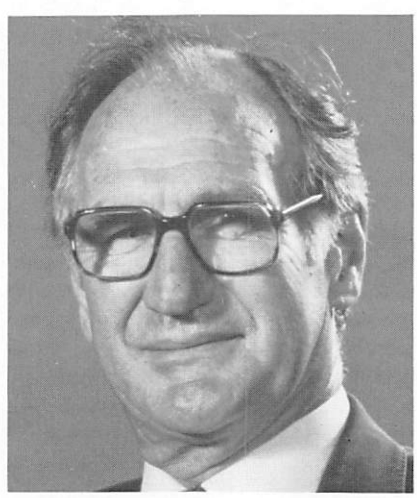
As agricultural and horticultural businesses became more specialised and technology advanced, so the Advisory Services responded by developing increasing specialisation at both national and local levels within their organisations. The knowledge and expertise so accumulated is now being applied to the provision of Services on a commercial basis as the industry adapts to perhaps the most significant changes experienced to date.



P L Redman

2 Early developments in England and Wales

Up to the beginning of the second world war there was no *national* organisation of advice to farmers even on basic subjects such as soils and fertilisers. Most counties had an Agricultural Organiser with responsibility for passing on to farmers results of scientific advances in crop varieties, fertiliser use, pests and disease, and some aspects of livestock production. A few regions arranged excellent contacts with locally situated national Research Institutes, Universities or Agricultural Colleges etc., but the haphazard nature of the provisions before the establishment of the National Agricultural Advisory Service (NAAS) in 1946 was justifiably much criticised.



J G Schiach

However, by the late 1930s the importance of scientific and technical developments to British farming efficiency was appreciated by governments, and when the war came action was quickly taken to set up County War Agricultural Executive Comittees (WAEC) to ensure increased crop production on a national basis.

At that time there was no "official" mechanisation advice available: nor was there any academic degree or other high qualification in agricultural engineering in Britain. It was fortunate that there was an Institute for Research in Agricultural Engineering at Oxford, and, as part of the war effort, the Institute and its small staff were soon moved to a first-class location at Askham Bryan near York, where additional staff and facilities were provided to enable the Institute, soon to be called the

Claude Culpin was formerly Chief Mechanisation Adviser of NAAS/ADAS. He is probably most widely known for his authoritative book, "Farm Machinery". He is a past President of the Institution. Peter Redman is Senior Mechanisation Adviser of ADAS. Hamish Shiach farms in Aberdeenshire and recently retired as Head of the Agricultural Engineering Dept of NOSCA. He is a past President of the Institution.

National Institute of Agricultural Engineering (NIAE), to carry out trials of new equipment and also to train a succession of Machinery Instructors. These, after short courses and occasional refreshers, were made competent to help farmers, usually by demonstration, to get the best out of relatively simple equipment such as tractors, ploughs, drills, binders, threshers, etc.

By the end of the war there were around 100 Machinery Instructors working under the supervision of County Agricultural Organisers or Technical Officers of the WAECs, and with a steady flow of useful technical information provided by the work of the NIAE. When NAAS was set up by the 1944 Act to service England and Wales, it was logical that advice on mechanisation should be made available to users on a basis comparable with that of some other specialist subjects such as dairying, poultry-keeping and horticulture.

By 1947, when the NIAE moved to its present location at Wrest Park, Silsoe, it had become clear that advice on mechanisation could have an important future, but that the work would need to be at a higher technical level than had normally been needed in war-time by the Machinery Instructors. Arrangements were therefore made by those responsible for the development of NAAS to establish a continuing connection between the NIAE and NAAS Mechanisation staff which would ensure on a permanent basis that important results of research and development would be rapidly made available to users. A small NAAS Liaison Unit was set up at Wrest Park from Day 1 of the NIAE's occupation, and this greatly facilitated such important objectives as achieving good and continuous in-service training of regional and county mechanisation staff. Objectives from the beginning included providing users with reliable information on machine performance and the best operating systems for common needs. Experience soon showed that much of the basic data needed, could, in fact, be obtained by well-planned field studies carried out by the advisory officers themselves. The first national-scale investigation (on silage-making systems) showed the way, and was quickly followed up by a series of other investigations of topical needs in a time of many changes of mechanisation systems. In the meantime, the developing work of the NIAE on subjects such as environment control in glasshouses, stock buildings, and fruit and vegetable stores led to a need for the NAAS Mechanisation group to help in securing success in new practical applications of advanced technology at the Ministry Experimental Centres and on leading commercial holdings. qualified specialists to work effectively at the Liaison Unit on adapting the Institute's work to users' needs. The wider application of all important new developments was continually fostered through national and regional refresher courses, and where appropriate by the preparation of advisory leaflets or technical reports arising from the NAAS national investigations.

By such means there were many early successes in what was originally an ambitious programme, so that by the end of the 1950s, NAAS Mechanisation Advisers had earned the respect not only of leading farmers and growers, but also of scientific and engineering staff working in NAAS and the NIAE, and of well-qualified agricultural engineers in general.

2.2 From the 1960s to a "commercial" Service

The continuing objective for agriculture, right through to the most recent times, has been to maximise self-sufficiency in food supplies by increasing efficiency and production. Government funded Research and Extension Services have made significant contributions throughout by improving understanding of the basic processes and by the development and application of more advanced technology. The role for Mechanisation initially was to improve the productivity of machines, but in recent years the emphasis has changed towards the more efficient use of inputs and the avoidance of losses and damage. Mechanisation Advisers played their full part in this challenging and rewarding work and the Advisory Service continued to attract well qualified staff — increasingly Agricultural Engineering graduates — but all with a practical bias and sound understanding of the agricultural and horticultural industries which they served.

During this time the objectives, methods, organisation and resources of the Advisory Service were adjusted several times to meet changes in the attitudes of Governments and the form of their support to the industry. The most obvious of these was the change from NAAS to the Agricultural Development and Advisory Service (ADAS) in 1971 when the Service was required to maximise its impact on agricultural productivity by being more selective in the type of work undertaken, by using the most cost effective techniques to disseminate information on a broad front and by being less "paternalistic".

As a result of these changes, the number of Mechanisation Advisers in ADAS had been reduced to about 60 by the mid 1970s, the majority of whom have been located in each of the Counties and later the Divisions of MAFF throughout England and Wales.

This wide geographical distribution placed these advisers in close contact with the problems and practices of the various farmers and growers in their area, a feature fundamental to all of their activities.

The nature and requirements of agricultural businesses changed appreciably from the early 1960s to the early 1980s. For many, improvements in efficiency were achieved by increasing scale and by specialising in fewer enterprises, aided and abetted by advances in technology and engineering in particular. Mechanisation Advisers have been in the vanguard of many of these changes, adapting their knowledge and expertise accordingly. Traditionally they have worked in close association with colleagues from all the other disciplines, research workers, machinery manufacturers and suppliers, farmers and growers. From this unique position they have a clear and early view of the specific mechanisation requirements of the industry and of the opportunities for new ideas and developments.

Nationally co-ordinated field studies carried out by Mechanisation Advisers continued to be an effective method of evaluating mechanisation practices as they developed and of obtaining basic planning data for advisory work. The information obtained in this way appeared in the form of NAAS Technical Reports, later to be known as Farm Mechanisation Studies, running to a series of some 36 reports on subjects ranging from pipeline feeding of pigs

Fig 1 John Deere 550 round baler (John Deere photograph)

to barn hay drying, and from crop damage in carrot harvesting to axial flow combines. Much of this information, combined with the experience of practising advisers and data from research and other sources, was translated into leaflets advising farmers and growers on the application of the full range of mechanisation techniques. This series of MAFF Farm Machinery Leaflets and Horticultural Machinery Leaflets (subsequently ADAS Mechanisation Leaflets) included many which were considered to be among the most authoritative literature on their respective subjects. Mechanisation Advisers have also passed on information by lecturing on all the platforms available from small discussion groups to National Conferences. Working demonstrations of new techniques were staged on farms, at shows and the like and have now become a prominent feature of many of the national events.

Important though these activities have been, advice direct to individual farmers has been the mainstay of their work. This requires the skilful combination of local knowledge, basic engineering and an understanding of agriculture and horticulture, all communicated effectively to ensure that the solutions offered are carefully matched to the individual concerned and his particular location and farming activity.

Working in this way, Mechanisation Advisers have made significant contributions to developments in forage conservation, crop protection, waste handling, energy conservation, to reducing losses at harvest and limiting damage to both the soil and crops. They have been involved in the development and application of drying and storage technology, protected cropping engineering and improved materials handling systems. More recently they have been prominent in resolving problems of straw incorporation, containing pollution and maintaining the quality of produce for more discerning markets. Inevitably, many have developed particular expertise related to the mechanisation prominent in the area in which they work, such as fruit storage, irrigation, greenhouse engineering, and so on, expertise being made available to colleagues elsewhere by the preparation of technical notes and by direct consultation.

The potential benefits of specialisation within such a broad discipline to match the advancing technology and specialisation within the industry was recognised even in the early 1950s and pioneered by allocating a post to allow specialisation in Glasshouse Engineering on a national basis as part of the Liaison Unit at NIAE. By the early 1980s, seven National Specialist posts were established at the Unit in areas such as Crop Production, Materials Handling and Control Engineering. Being located at Silsoe, these National Specialists are ideally placed to achieve the closest integration with research colleagues in the two-way flow of information. They lead the collection and dissemination of information within the discipline and back-up the advisory work of colleagues in the regions.

This organisation has served the industry well in its quest to increase production but it has been generally recognised in recent years that agriculture has now met this objective. Consequently many are searching for new opportunities and looking to changes in practice to maintain profitability against a background of increasing public sensitivity to issues such as animal welfare, pollution and the environment in general. Coincidentally, the Advisory Service has been required to generate revenue from many of its activities from April 1987 onwards. From the first year's experience, it is already clear that the addition of this commercial dimension could well bring about the most significant change in the Advisory Service to date. Resources will need to be concentrated on to those subjects and activities with the most commercial potential to the exclusion of others, always with an eye beyond the short term. New markets for Mechanisation Services will need to be examined outside the more traditional topics and territories and professional standards will be pushed even higher. There can be little doubt that engineering will be a key component as both the Agricultural Industry and Advisory Services adapt to these changes and that the professional knowledge, techniques and reputation for impartiality developed over the last 50 years will provide a sound basis for the years ahead.

3 Mechanisation Advisory Services in Scotland

Scotland has a long tradition of having its Agricultural Education, Advisory and Development Services being provided by three Colleges of Agriculture: The East of Scotland College (ESCA) based at Edinburgh, The West of Scotland College (formerly WOSAC, now WSC) for long in the city of Glasgow but more recently at Auchincruive, Ayrshire, and The North of Scotland College (NOSCA) in Aberdeen. All three have always had strong links with their local Universities.

For most of their history, the three

Colleges have been independent limited companies and were very proud of the independence and impartiality which this gave them. More recently they have amalgamated under an umbrella organisation called Scottish Agricultural Colleges with its Headquarters at Perth which is convenient for all three.

In their early days the Colleges had strong links with local government but progressively, funding was more and more by direct grant from the Department of Agriculture & Fisheries for Scotland (DAFS). This trend has been reversed by the introduction of charges for a wide range of the services provided by the Colleges.

The earliest advice available to farmers on the use of machinery came towards the end of the 1939–45 war when staff were seconded from DAFS to the Colleges. The reasons for this had much to do with direction of labour and reserved occupations under wartime regulations. The secondments made it possible for the civil servants from DAFS to work with the Colleges.

The numbers were small but it was a logical development since DAFS had controlled the availability of machinery during the war, the machines either being made available for purchase or for hire through a contracting network operated by DAFS.

The secondees from DAFS were transferred to the Colleges on 1 May 1947 when the Colleges were required to expand their Advisory Services under initiatives flowing from the 1944 Agriculture Act. The numbers involved with machinery advice built up from the original half dozen to around 15.

The job title was Machinery Instructor and the holders of the posts came from a wide range of backgrounds. Most had been trained within the agricultural dealer network but others came on demobilisation from the armed forces where they had developed skills which could be utilised in what was almost another war, the need to increase agricultural output from the country's own resources.

In 1947, the horse was still a prime source of power on farms and these Instructors were much in demand by farmers unaccustomed to the foibles of the internal combustion engine or the behaviour of a plough when the stilts were not held in the hands.

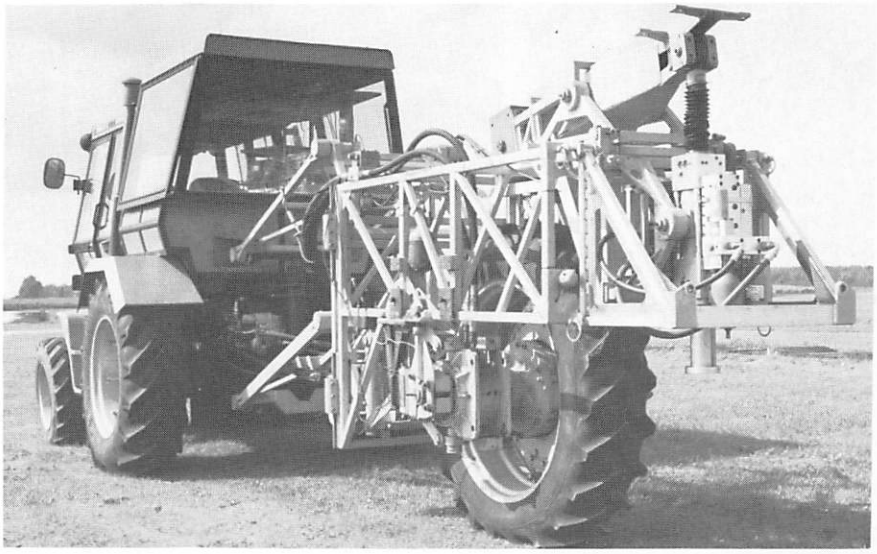


Fig 2 Single wheel tester used on tyre research (AFRC Engineering 'photo)

The Instructors were, of course, complementary to the staff of the distributors of farm machinery and a *modus vivendi* had to develop depending on local circumstances. For example, an Instructor working in the Northern Isles of Orkney & Shetland could quite easily be running courses on fitting big ends to crankshafts, where his colleague in an intensive arable area would quickly have been drawn up short by the local dealer.

A large part of the Machinery Instructor's work was in making it possible for farmers to see the vast range of machinery which was being introduced in those early days of mechanisation to Scottish farms. Demonstrations were organised all over the country on the use of such things as hydraulics for lifting and operating implements; mounted ploughs; dung loading and spreading; and the introduction of the ubiquitous buckrake to the silage field.

These Instructors also had a big educational role. Formal courses, often leading to the City & Guilds Institute of London qualifications, as well as evening classes on specific topics, became part and parcel of the job. An unusual task in the early post-war years was helping with the training of "displaced persons", especially from Eastern Block countries, to help to integrate them into Scottish agriculture.

In the middle 1950s the decision was taken that all advisory staff should be at graduate level. This caused traumas within the machinery advisory service but eventually, after they survived an interviewing process, all the machinery instructors were transferred to the then NAAS Grade III.

The 1950s in Scotland saw the combine almost totally replacing the binder as the harvesting machine for cereals and the consequent drying of grain provided the major activity for the machinery service for at least the next decade. Whether Britain was right to encourage on-farm grain storage is debatable but it did lead to 1001 solutions on individual farms. Many of the systems only worked because of stalwart work done by the Machinery Instructors.

Towards the end of the 1960s it became apparent to College Management that farmers were asking different questions about machinery and that the concept of mechanisation and its management was becoming more important than instruction on individual machines. Graduate staff in a wide range of disciplines were becoming available and the problems in soil management, environmental control, waste systems, milking installations and many more were demanding a more specialised approach.

From the inception of the service, the Machinery Instructor had been managed within the General Agricultural part of the service. The need to change was reflected first in a change of job title to Mechanisation Adviser and, gradually over the 70s, the three Colleges moved the Mechanisation Service under the management control of Agricultural Engineering Departments. At the same time there began to be an appreciation that Farm Buildings Specialists were closely allied to their Agricultural Engineering colleagues and throughout the 70s and 80s there had been increased integration between the two disciplines.

One area of work which caused great anxiety over the years was the demand by farmers for a testing service on individual machines. An objective pre-production testing service had been shown to be not only too expensive but also of limited value to the user (although not necessarily to the manufacturer).

The professional experience of the Mechanisation Adviser proved of immense value in this context. Just as the early Machinery Instructor had to trim his activities to the interests of the distributive trade, so too had the Mechanisation Advisers to act wisely. It says much for their wisdom and professionalism that few problems arose.

From the beginning of the Service, Instructors and then Advisers had been involved with monitoring, calibrating and developing machinery. As the years passed, Research was added to the functions and the Mechanisation Adviser became a regular contributor to Learned Journals and the Research Programmes of their Colleges and Universities.

The development of the Mechanisation Advisory Service in Scotland took place over some forty years of increased Central Government funding. The result was the availability of a highly professional, impartial service to the farming industry of Scotland.

The large reduction in financial support in recent years has necessitated the emergence of a Lead Centre Concept within Scottish Agricultural Colleges. This has led to major reductions in staffing and this, combined with the need to charge for services, may mean a service in contact with many fewer farmers. The two-way flow of information between farmer and adviser, which over the years has led to many important advances in mechanisation, may now be stifled.

Agricultural Engineering in Third World Countries 1938 to 1988 — Part I

B A May

Summary

THE subject of this review paper is important, vast*, complex and sensitive. A special approach has therefore been considered necessary in its treatment and the background to this is given in the Introduction.

The paper sets out to recognise and describe some of the contributions made by the agricultural engineer, both local and expatriate, to agricultural development in Third World countries during the past fifty years. Some of the technical achievements and business endeavours of agricultural engineers in the Third World are discussed. All this is put in the broader context of fifty years of Third World development. The development of agricultural engineering as a profession is also considered together with a review of the special features of progress in the fields of agricultural engineering teaching and research.

Future possibilities for agricultural engineering contributions to Third World development are suggested in the final section.

1 Introduction

This paper is about agricultural engineering in Third World countries during the past fifty years. The task may have been difficult enough to have selected a single Third World country for review: To include them all and to do justice to the subject over a fifty year period seemed at first to be impossible!

I have been involved personally in Third World Development for much of the period, making my first working visit some 34 years ago. Since then I have worked in more than fifty developing countries, but I regret to say that my experience is limited to an average of just over one month in each!

Whilst at Silsoe I have been part of a team which, over the past twenty-five years, has welcomed several thousand Third World Study Fellows for a wide range of teaching, research and practical training assignments. Some have helped me in the presentation of this paper, for which I am grateful.

My approach has been to present a personalised review aimed at giving general impressions, together with selected detail. I apologise in advance for my prejudices, for the inaccuracies which arise from the liberal use of generalisations and for the serious omissions which I sense must be there — I wish I knew where! For the complete untruths I can only plead that they were made through ignorance rather than any intention to deceive.

In anticipation of cause for comment in each of the above categories of potential error and to allow for further points to be raised on such an important topic by those better qualified than I, I have made a special request of the Honorary Editor. I am pleased to report that he has agreed to run an expanded 'Letters to the Editor' section for the middle two issues of The Agricultural Engineer in 1989. You do not have to be an Institution member to contribute. I look forward to reading your contributions and in the meantime hope that you will agree that I have at least gone some way towards achieving the objectives of this article which were:

- to recognise the contributions made by agricultural engineers, local and expatriate, to agricultural development in the Third World during the past fifty years.
- to identify some of the agricultural engineering technical achievements and challenges in the Third World and
- to suggest some possibilities for future agricultural engineering contributions to Third World Development.

Finally, I should like to thank all those agricultural engineers in the UK and overseas who have sent me contributions and references for this paper.

2 The Context — 50 years of Third World development

'We have seen the awakening of national consciousness in peoples who have for centuries lived in dependence of some other power... In

Professor Brian May is Head of the Cranfield Rural Institute which forms part of the Cranfield Institute of Technology, Bedford. He is a past President of the Institution.

*Because the subject is so vast, the paper will be published in two parts. Part II will appear in the next issue of the Journal different places it takes different forms, but it is happening everywhere. A wind of change is blowing through this continent, whether we like it or not.' This view of the African continent was given by Harold Macmillan in 1960. In the 50s and 60s, Africa was passing through a period of rapid change and great optimism as the Independence Movement gathered momentum. Independence and much of what happened previously in Africa is described in a clear and authoritative manner by Oliver and Fage (1988). In the 30s and 40s the Third World generally had experienced the struggle to survive the effects of World recession and the devastation of the Second World War.

Third World agriculture was largely organised and managed by Europeans. In the 50s voices were beginning to be raised locally that too much attention had in the past been given to export crops at the expense of food crops. Recovery from the economic pressures of recession and the War effort took priority which meant that little attention was given to the advancement of agriculture in any form until well into the 60s.

Consequently, agricultural engineering began to emerge in the Third World some thirty years behind Europe and still further behind North America.

The experiences of recession and war on a global scale led to the concept of food security taking a firm hold in the minds of many politicians. This concept, together with agricultural priority and farmer support systems was subsequently to form the basis of food policies initially in Britain and North America, but later in many other parts of the world.

The effects of these food policies and our ability to modify them are of course one of the major challenges facing the world today. Agricultural engineers are deeply involved with many of the issues and possible solutions.

The War gave a new word to the colonial vocabulary — development. The word has since become widely and frequently used in the context of Third World affairs. 'It has to be remembered that a country like Tanganyika was chronically short of money between the wars' explains Charles Meek (Allen Charles 1979) 'so there was nothing whatsoever to spend on development. Each colony was supposed to subsist on its own and if you had very little, as Tanganyika did, in the way of primary produce in high demand, sisal, cotton, a bit of coffee, then the country was going to be hard up — and poverty stricken it certainly was. It was only during the War with the passage of the first Colonial Development and Welfare Act that the coming of better times was signalled. They were slow in coming, but slowly the momentum of development did build up and the pace got faster and faster.'

There was a negative, often paternalistic, side to British colonial rule that was nevertheless, in the opinion of most of those who served in the African colonial territories, outweighed by its merits. 'In our moments of depression we would wonder whether really we were doing any good' declares Sir Gerald Reece. (Allen Charles 1979) 'I myself came to the conclusion that the British were doing more than perhaps most other nations would do in that we were serving a purpose. Undoubtedly we interfered with the Africans, sometimes by trying to introduce our own way of life which didn't suit them, but, on the whole, I believe that the British did set an example for them to follow if they wanted to do so. Our attitude to such things as honesty and tolerance, our belief that an absence of bribery and corruption amongst officials produced the best results, and above all the idea that if we have a responsibility and are put in charge of others, it is up to us to serve the people in any way we can. That was a great lesson I think that the British left behind in Africa.'

What was the effect of the British presence in Asia? Norman Watney worked as a Mechanical Engineer in India and Pakistan for almost thirty years from 1925. In his opinion, (Allen Charles 1976) 'The fashion is to judge India by the few people who made money out of it and forget the devotion of the people who served it. The men who looked after the forests, the people who built hospitals, the people who made roads, who did the irrigation. It was their occupation granted, but they did it with a love of India, a love of the people, and what they did and what they contributed is now forgotten to a large extent. They were the ordinary, plain little people, the ones in the middle who were never exalted, but who ran India really.'

In South East Asia where the effects of the Second World War were particularly severe, conflict lingered on well beyond the end of full-scale war involving notably the peoples of Malaysia, Korea, Vietnam and Cambodia. The Emergency in Malaysia, for example, lasted for more than a decade. This had a serious disruptive affect on the plantations, especially rubber, and by reaching into the most remote kampongs produced tragic loss of life and a general demoralising influence on the Malay population as a whole. Developments in agriculture in terms of food and export crops were thus very limited in Malaysia, and many other South East Asian countries until well into the 60s. Subsequent development was particularly rapid and successful in that part of the world, assisted by the application of engineering advances, especially in land clearance, irrigation, crop and plantation management and processing.

In the North, growing concern was being expressed during the early 60s about the plight of those living in the Third World. Dwight D. Eisenhower, during his last term as American President, said 'There are one billion seven hundred million people living today without sufficient food, clothing and health facilities. They are not going to remain quiescent. I think the problem of the under-developed nations is more important for Western Civilisation than this problem of the Soviet-Western differences and quarrel. If the Statesmen of the World do not make the problem of the starving millions the foundation of all their work for peace they must necessarily fail.'

Despite such calls for peace, together with much optimism and progress in the 60s, the Third World has been unable to rid itself of conflict which has persisted through the 70s and 80s. This has arisen in many forms, for many reasons and has affected many countries, leading to misunderstandings, mistrust, negative reactions and sometimes isolation. Economic difficulties have continued despite the aid programmes, formal and informal, and calls for action necessary to reverse the ever-widening economic gap between the North and South.

The Pearson Report published in 1969 (Partners in Development 1969) suggested that the declining foreign aid appropriations in the closing years of the 60s indicated a crisis of confidence in the capability of low income countries to master the massive problems confronting them.

The World Bank President asked Lester Pearson, former Canadian Prime Minister and Nobel Peace Prizewinner, to undertake a study of the consequences of 20 years of development assistance and on the basis of such a study to offer solid proposals for a global strategy in the 1970s and beyond.

A comprehensive analysis of development aid to date was thus produced alongside a full-scale treatment of development in the coming decades. A new basis for international cooperation was proposed and the responsibilities of both donor and recipient spelt out.

In 1980 the results were published (North-South 1980) of a further major review.

The review drew attention to the seventy percent or more of the poor in developing countries living in rural areas. 'In the past,' the Report suggested, 'many countries have put disproportionate efforts into developing the urban and industrial sectors. But the neglect of agriculture has often caused per capita food production to stagnate or even fall and food prices to rise. Rural poverty has thus increased and inequality has become wider. We (the Independent Commission on International Development Issues) believe that a necessary condition for fast overall growth, is sustained increase in agricultural production especially in food crops. This will call for a higher proportion of development funds to be directed to rural areas for infrastructure, credit, storage, marketing, extension services, research, agricultural implements and production inputs such as, fertilisers, and improved seeds and pesticides.'

The strengthening of indigenous technological capacity often requires a more scientific basis in education, the encouragement of a domestic engineering industry, increased emphasis on intermediate technology and the sharing of experience. There is an urgent need to provide new incentives to develop appropriate technologies and, almost equally important, to make them known to everyone. There is also a need for more research into adapting existing machines; a need to know more about which technology is most useful to a particular territory; a need to see case studies of where and how different systems have worked.

The prospect for understanding and implementing these ideas was clearly dependent upon effective communication between the peoples of the North and South. Sir Shridath Ramphal (1979) put it this way at a Conference: 'The problem of different perceptions of the world lies at the heart of global misunderstandings. The picture of the world is just not the same from Washington or Bonn as it is from a jute plantation in Bangladesh or the arid scrubland of a village in Mali. It is perhaps natural that the advantaged do not readily discern what is wrong with the world; but the view as it is seen by two-thirds of mankind that is disadvantaged, is itself one of the realities of the global scene. Even if this view is not shared by the North, there can be no fruitful dialogue unless it is understood as the perception of the South. If it is at least acknowledged as such it will become easier to understand why the developing world calls for a new order.'

The achievement of a global 'new order' has proved elusive up to the present. Locally, however, new orders have come — and sometimes gone — on several occasions. Political, economic, social and religious factors working individually and in combination, can produce rapid and marked shifts in local development practices and priorities. For example, Sir Emrys Jones (1975) referred in the First Douglas Bomford Memorial Lecture to 'the booming oil based economy and a stable political situation' which in Iran 'have made possible a significant upward revision in the original targets set out in the Fifth Plan.' The local situation is very different today.

All of these matters are inevitably influencing the work and progress of the agricultural engineer in Third World agricultural development. Failure to resolve the issues increases significantly the chances of famine and malnutrition in the poorest countries. It diverts effort from winning the vital race between population growth and food production in many regions of the Third World. Above all, it limits relief of the most fundamental and continuing problem in much of the Third World — poverty. The World Food Conference organised by the European Parliament in April 1988 was concerned with the 'practical problems' facing governments in the current worldwide debate on agricultural reforms. Lord Plumb, President of the European Parliament and Chairman of the Conference hopes for an immediate reaction from world leaders. 'Time is running out,' he says. 'If we are to do something about rural poverty in the Third World, the industrialised world must get together to do it, and must do it in partnership with the Third World.'

Partnerships in developing countries were discussed in the 1985 Presidential Address of this Institution. (May 1985) Partnerships are necessary because 'in many

Plate I. A Ferguson TE 20 tractor being demonstrated near Cairo, watched by Latif Al Mardanly Bey, Minister of Agriculture and by colleagues

situations the engineering solution may be simple but making it appropriate, affordable and useable by the farmer can be intellectually demanding and elusive in a practical sense leading to frustration and failure, particularly if the realities are not considered.'

I put these issues and the steps being taken, to some mid-career Africans studying agricultural engineering at Silsoe. Their comments were polite, but sharp and to the point. 'Too little too late' said one, while another questioned whether 'the aggressive campaign of the US to maintain agricultural exports, the consequences of European Community surpluses and developments within GATT, (the General Agreement on Tariffs and Trade) and the 1992 EEC harmonisation would produce anything but a worsening of the Third World position in terms of agricultural production, trade, balance of payments, and the ability to service loan debts.' They had seen the potential for agricultural engineering contributions in their own countries but doubted whether the potential could be realised until these issues were seriously addressed. 'Only time will tell' observed a Marketing Study Fellow from Nigeria, 'But will there be enough time to get results acceptable to the Third World?'

In a keynote address to the World Food Conference, Zambian President Kenneth Kaunda said that a simple transfer of food surpluses from the northern hemisphere to the poorer countries in the southern half of the world brings no solution if such food aid 'is not accompanied by measures to help develop farm production in the poorer countries.'

In the 1970s a series of UK conferences offered hope for greater co-operation between nations on major issues, particularly in connection with the environment. The 1972 UN Conference on the Human Environment for example, brought together the industrialised and developing nations to identify the basic 'rights' of the human family to a healthy and productive environment. Several meetings followed concerned with the rights of people to adequate food, to sound housing, to safe water and access to means of choosing the size of their families. In the Third World, the agricultural engineer has an involvement in technologies for food production, building construction and water supplies. Can more be done in the future by agricultural engineers to improve the well-being of rural communities?

Environmental issues are of prominent concern in the present decade demonstrating, as with economic issues and matters of agricultural reform, that they can only be effectively addressed on a global basis. Thus the Third World is increasingly seen as part of one world. The agricultural engineer, together with other professionals must recognise this.

'Scientists bring to our attention urgent, but complex, problems bearing on our very survival' writes Ciro Harlem Bruntland, (Our Common Future 1987), Prime Minister of Norway and Chairman of the World Commission on Environment and Development. The problems include 'a warming globe, threats to the earth's ozone layer, deserts consuming agricultural land. We respond by demanding more details and by assigning the problems to institutions ill-equipped to cope with them. Environmental degradation, first seen as a problem of the rich nations and a side effect of industrial wealth, has become a survival issue for developing nations. It is part of the downward spiral of linked ecological and economic decline in which many of the poorest nations are trapped.' What can the agricultural engineer of the future do to help to resolve some of the underlying ecological and environmental problems which currently exist in many regions of the Third World?

3 The development of agricultural engineering as a profession

Agricultural engineering began to develop as a profession in the Third World in the 1960s some thirty years after the founding of our Institution in Britain. Previous to this, agricultural engineers from Britain and other countries in the North were working on an expatriate basis as advisers to Third World governments, often within technical co-operation elements of aid programmes. These people made, and are continuing to make, an important contribution to the local development of an agricultural engineering profession. It should be emphasised that this slower rate of development of agricultural engineering in the Third World was caused by circumstances rather than any limitation or deficiency amongst the people. The constraints of colonialism, the demands of Independence and continuing economic pressures have already been mentioned. There was also a lack of any significant scientific and industrial base upon which to build the engineering and technology support for a mechanised agriculture. Civil, mechanical, chemical and electronic engineering, all important ingredients of the modern agricultural engineering mix were also in the early stages of development. Exceptions to this general statement arose in those areas where railways and roads were being established and developed to link urban and industrial enterprises to the airfields and ports. This was, however, largely an expatriate initiative. When these branches of engineering began to develop further, the associated professional skills were focused on higher priorities such as industrialisation, urban developments and services, airports, defence installations and the exploitation of mineral resources — where they existed. Boutzev and Faye (1987) suggest that the main indicator of economic development in the modern world is the level of productivity which is related to the technological development of a country. They also propose that the professional competence of engineers and technicians determines the technological capabilities of a country. Figures 1 and 2 give information about engineers in employment and in training for a number of developed and Third World countries. A similar pattern exists for technicians. To help to redress this imbalance the authors urge that a focus on training is required in key areas such as rural development, agricultural engineering, civil engineering, mechanical and construction engineering, mining and the agro-food industry.

Assessments of professional manpower needs for specific tasks are also important. Projected irrigation manpower requirements for Nigeria (Carter *et al* 1986) are given in Figure 3. In developing countries, the essential technicians, craftsmen, artisans and skilled

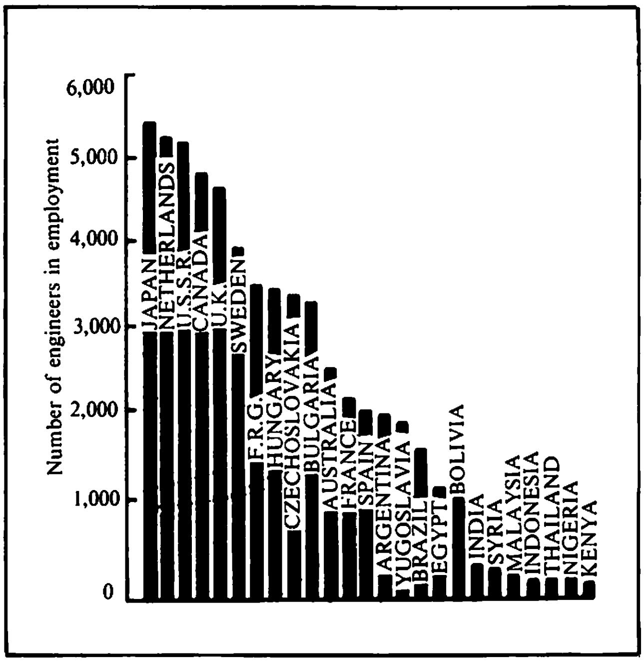


Figure 1 Number of engineers in employment per 100,000 inhabitants

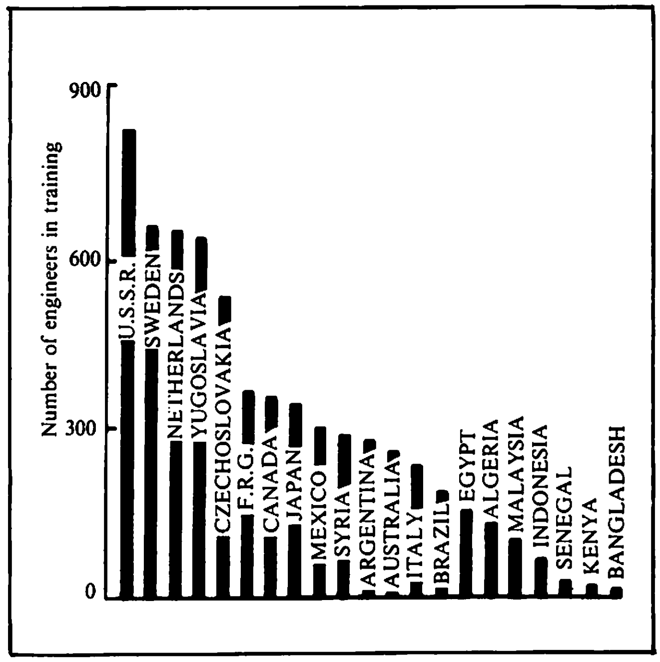
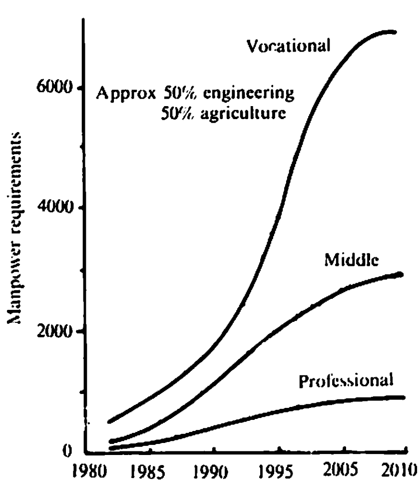


Figure 2 Number of engineers in training per 100,000 inhabitants

operators were sometimes developed locally, but in the main were imported. This applies especially in the Middle East and has caused a number of developing countries to count on the earnings of migrant workers as a critical source of foreign exchange. Pakistan, for example, receives almost as much from its workers abroad as from its total exports. Egypt, Sudan, Bangladesh and the Philippines are also significantly dependent upon migrant worker earnings. Despite its foreign exchange attractions the migrants are often insecure and subject to discrimination — a recession can rapidly end their contracts, sending unemployment

Figure 3 Projected irrigation manpower requirements for Nigeria



back to their own country. The labour market like the market in commodities or manufacturing in the Third World has weak sellers and powerful buyers. Migrant workers are often the best workers. The loss of high-quality professional engineers and technicians from the less fortunate developing countries must be set against the foregn exchange benefits.

In South East Asia local development of technical skills has been particularly successful. There is a massive reservoir of such skills underpinning the professional inputs. The people are versatile and adaptable, capable of assembling sophisticated circuit boards in electronics factories or fabricating replacement lorry springs in backyard workshops. Some of these have spilled over into agriculture with great benefit to the advancement of professional agricultural engineering. Examples include Korea, the Philippines, Malaysia and Thailand. India of course is a Third World leader in this respect.

Industrialisation has not made significant progress in many parts of Africa. Consequently, support for the development of an agricultural engineering profession has been limited. The engineering professions in general have developed less rapidly in Africa and there are continuing losses from the profession to other career opportunities perceived as being more attractive and rewarding.

Despite the consequences of a generally lesser industrial base in the Third World countries, many career opportunities for local agricultural engineers have been arising, particularly in the late 70s and 80s. Teaching, research and extension in government departments receive a major flow of agricultural engineering graduates. Demand is also growing for agricultural engineering managers of irrigation installations, machinery centres, agricultural projects, process plant and workshops. Technical advisers are regularly sought for agricultural banks, co-operatives, State farms and municipality parks and leisure centres. Sales, marketing and technical support is also needed from agricultural engineers by local manufacturing companies, importing agencies and the principals of joint venture operations. Plantation industries, forestry, consultancy and aid agencies are also becoming aware of the particular attractions of staff members combining an understanding of agriculture with abilities in engineering.

Recognition of agricultural engineering as a profession alongside established scientific and engineering disciplines has been a challenge for decades in Britain and other countries in the North. There has been a similar experience in the Third World. Some of the difficulties can be traced to the translation and definition of the terms agricultural engineer, ingenieros agronomos, ingeniero agricola, ingenieur de conception, ingenieur de travaux and genie rural. These difficulties mainly arise from the academic and professional concepts and particular influences of the Europeans and Americans. In the Arab world the term 'engineer' is increasingly used to mean facilitator or manager, which produces an even wider range of definition for the agricultural engineer. It should also be recognised that in most Third World countries agricultural engineering has developed from an agricultural rather than an engineering base. Curiously, agriculture throughout the world has few professional groupings for its participants. This lack of professional identity has only become of concern in the Third World since the late 70s as the wish to become recognised as engineers has developed. The Indian Society of Agricultural Engineers was one of the first to be formed in 1960. Other Societies operate in many countries of the Third World, for example, in Korea, Thailand, China and Nigeria. Almost ten percent of members of the Institution of Agricultural Engineers are from overseas. Table 1 shows that Third World overseas membership in 1988 is forty-one percent greater than that from overseas developed countries. There are also around two and a half times the number of Third World countries represented compared with developed countries.

Table 1 Institution of Agricultural Engineering UK overseas membership, May 1988

Region	Number of countries	Total membership
Developed countries	15	123
Third World countries	39	174
Totals	54	297

The significance of professional identity becomes important when we seek to establish standing and priority for agricultural engineering in the Third World. The reasons for this must be seen as being associated with the status of the profession and not the individual. This applies in many Third World countries where culture, religion and social codes of practice limit, sometimes prohibit, open promotion of the individual. Identification and development of needs of the individual in professional agricultural engineering has previously been considered by the author (May 1979).

For effective leadership the individual must be willing to earn the respect of others in ways which have not always been apparent in the past. In the words of Lord Forte, one of Britain's most successful businessmen, 'You cannot get results simply by sitting back and giving orders. You have to get down to the nitty-gritty of the business. The people who work with you must be aware of the fact that you know the ins and outs of the business as well as they do, that you are prepared to work with them at all times and that you are not the last to come or the first to go.'

What are the issues which might become the focus of interest for professional agricultural engineering groups in the future?

According to a recent article (African Women 1987), women provide forty-six percent of the agricultural labour (for food and cash crops) and produce eighty percent of the basic foodstuffs in black Africa. Agricultural engineering clearly has much to offer women in terms of relief from drudgery and increased productivity in cultivation and processing of crops. Perhaps more women should be encouraged to join the agricultural engineering profession in the Third World!

Broad issues of intermediate technology and advanced technology might also be addressed. Schumacher (1974) laid the groundwork for a major thrust in support of technology suited to the needs of subsistence and small farmers. McRobie (1982) prepared a sequel to this work. Lord Caldecote (1984) discusses the possibilities for application of advanced technology by engineers in society.

Consideration of these issues in the context of agricultural engineering contributions to rural needs could be an eminently worthwhile activity for professional institutions.

The 'people factors', many of which relate to the individual, are major determinents in the progress of any profession. The agricultural engineering profession will continue to need the services of Norman Watneys 'ordinary, plain little people'. In addition, agricultural engineering in the Third World will need to attract more leaders, innovators and entrepreneurs. People who are dynamic in their action, but sensitive and responsible in their manner. People who are capable of working effectively as part of developing countries. The efforts necessary, but also able to lead, to see the 'big picture' and to interpret it imaginatively for the benefit of farmers large and small, rich and poor, and of all those serving the farmer.

One of the most important tasks for professional institutions in the years ahead will be to promote confidence and encourage investment in professionals and their work. This is unlikely to be achieved through scientific and technical endeavour alone. In the Third World a broader-based effort should be focused on the consumers of professional services, government and aid agencies.

According to a recent British Government White Paper published in January 1988 (The Government's Expenditure Plans), the provision for the overseas aid programme is planned to grow in real terms over the next three years. For aid to be effective, says the White Paper, recipient countries must have an appropriate policy framework including a soundly-based investment programme, concern for the environment and the development of human resources, and the creation of a climate in which initiative and enterprise can flourish. Professional agricultural engineers should play a full part in helping to achieve the appropriate environment in which they can attract funds to practise their skills effectively.

4 Agricultural engineering teaching and research

The university teaching of agricultural engineering in the North began in the late 50s and 60s. The United States, Canada and Australia have all played a leading role in this initiative which attracted students from the Third World, especially to the United States. In Britain a small number of Third World students were accepted for postgraduate studies in agricultural engineering at Durham and in mechanised agriculture at Reading. Following a paper presented by Peter Payne (1962), first Principal at Silsoe College, Peter Hebblethwaite said that he felt one of the most important functions of the recently established College was in its contacts with countries overseas. Not only would it be concerned with the training of students from this country to work overseas, but also the training of students from overseas. During the past twenty-five years the College has trained several thousand Third World students through under-graduate and postgraduate studies, short courses and professional development programmes. Table 2 gives a breakdown by region of the postgraduate Third World students at Silsoe, most of whom have studied agricultural engineering subjects.

Table 2 Third World postgraduate student numbers at Silsoe 1965–1988

Region	Number of countries	1965–1970	1970–1975	1975–1980	1980–1985	1985–1988	Totals
Africa	22	9	94	134	341	276	854
Americas	20	10	18	35	29	33	125
Asia	16	27	43	78	88	119	355
Middle East	9	14	25	32	31	38	140
Totals	67	60	180	279	489	466	1474

According to Professor Moens, (1983) the study of agricultural engineering was established at Wageningen in 1955. 'Now in 1981 more than 200 agricultural engineers have already finished their studies and are employed in all kinds of professions at home and abroad. Ever since its formation the Agricultural University has paid much attention to programmes of training and research for the benefit of developing countries. The efforts on behalf of the Third World are currently estimated at twenty percent of its capacity and are aimed at many countries in Asia, Africa and Latin America.'

In the 60s and 70s, as those trained in agricultural engineering began to return to their home countries, the subject was introduced in overseas universities.

Progress was generally slow, although in India agricultural engineering quickly became established within a well-founded university system. In 1967 at an FAO Conference on Higher Education in Africa (Proc. Conf. on Higher Education 1967) the Vice-rector of Ain-Shams University Cairo, demanded a substantial expansion of the pure science content of agricultural degree courses with only the briefest mention of Farm Mechanisation as 'one of the main components of the general course.' No reference was made to agricultural engineering.

The Dean of the Faculty of Agriculture, University of Nigeria Nsukka, said 'As the economy matures, additional departments will be developed to accommodate new demands. Agricultural Mechanisation represents an industry with a potential need for university men.'

Discussing the structure of higher agricultural education in the French-speaking countries of Africa, M. Rossin, General Inspector of Agriculture for the French Government, observed that North African schools concentrate on special problems in connection with Mediterranean agriculture. Special emphasis is given in their curriculum to certain technical problems: anti-erosion techniques, soil conservation, management of irrigated areas and water requirements of plants, mechanisation of agricultural production, processing of agricultural products and crop storage.

The inaugural conference of The Association of Faculties of Agriculture in Africa was held in Nairobi in 1973. (Proc. Conf. on Higher Education 1967).

In his opening address, Arap Moi, then Vice-President of the Republic of Kenya, observed that 'one of the greatest dangers that persisted in Africa and indeed throughout the developing world, is that of stereotyped reception of ideas that may be perfectly adapted to circumstances elsewhere, but which do not take account of the conditions and traditional patterns of life in our societies.'

Some of the perceptions and challenges for postgraduate education in the African universities were summarised by Professor Osman from the University of Khartoum. He suggested that the copying of postgraduate programmes from highly industrialised and developed countries is unlikely to succeed because of differences in climatic zones and development levels. The objective of postgraduate training should not, in his view, be only to produce specialists in research, but should include the task of training extension workers and production specialists. He believed that the best programmes for Africa are not necessarily the most sophisticated ones. This, he stressed, is very important in the light of the great expense involved in postgraduate training.

Professor Taylor from the University of Ibadan, talked about the basic structure of Faculties of Agriculture. His view of agricultural engineering was that it should be added to the basic structure. 'This is, of course, a very expensive department to run and to staff adequately.'

'I have shown it as an additional department because I believe it is possible to achieve many basic results in agriculture even in the absence of such a department.' This view was not challenged during the discussion which, together with the session, was chaired by Dr. Bol Alima from Cameroon, currently Ambassador in London. The relationship between Nigerian manpower needs for agricultural engineers and local university development has been fully reported by Nwa (1982). Between 1977 and 1980, 500 additional agricultural engineers were needed. To meet the needs of the country's mechanisation programme it is estimated that about 4000 engineers should be graduated by the year 2000.

Postgraduate education in Agricultural Engineering was reviewed by a Latin American Panel on Postgraduate Education (1969). The Panel concluded that 'At the threshold of the 1970s, education in all its branches has advanced to include science and knowledge unknown only a few years ago. Agricultural engineering has a major objective to effect improvement of social and economic conditions of rural communities in agriculture. This can be achieved through a harmonious integration of mathematics, physical and biological sciences with engineering in the following areas:

agricultural mechanisation and automation;

soil and water management, utilisation and conservation;

rural planning and construction;
preservation, handling and processing of agricultural products.'

In Mexico, support for the development of agricultural engineering came from the highest level. In his second State of the Nation Report delivered on 2nd September 1978, the President said, 'We have not yet attained sufficient harvests of some basic products such as corn, nor have we produced everything at prices that are both profitable and affordable. We must therefore continue attending to such key necessities as mechanisation, organisation, training programmes for producers, rehabilitation and levelling of irrigated lands and the expansion of cultivated area.'

In 1978 the Faculty of Engineering at the University of Guanajuato proposed the establishment of agricultural engineering as a career in Mexico. A National Committee for Agricultural Engineering was formed and a new Faculty of Agricultural Engineering established on a green field site at Irapuato during the period 1979–1983. Following early visits by Derek Sutton of ODA, the planning of this Faculty and its initial development were undertaken with the assistance of a co-operation programme with Silsoe College.

One of the earliest agricultural engineering initiatives in South East Asian universities was at the Agricultural University in Malaysia. Following initial advice from Iain Gibb in 1974, a Faculty of Agricultural Engineering was established in 1975 with the primary objective of providing a programme of study in agricultural engineering 'of a standard comparable with similar programmes offered by other universities of reputable academic standing and to meet the academic requirements of the Institution of Engineers Malaysia.' Silsoe College established a co-operation programme with the Faculty from 1976 until the early 1980s when Newcastle University agricultural engineers began to make advisory visits.

Agricultural engineering teaching and research in Tanzania is focused on the Morogoro Campus of the University of Dar-es-Salaam. Frank Inns was seconded from Silsoe College from August 1977 to the end of July 1980 as FAO Professor of Agricultural Engineering. An undergraduate programme in agricultural engineering now has been established in the university and plans are well-advanced for postgraduate courses. Since the early 1980s Newcastle University has been co-operating with the Tanzanian staff in the development of courses and presenting some lectures.

Agricultural engineering features prominently in education and research in China. Professor Wang Mao-hua, Vice-President of the Beijing Agricultural Engineering University (BAEU) reports (Wang 1986): 'From the beginning the development of agricultural engineering (in China) has a national basis of international co-operation. In the 1940s a group of young Chinese scholars who are now all over 60, diligently studied in America. Most of them came back to China around 1949 when the new China was founded and became pioneers of developing the Chinese agricultural engineering science.'

Today, China has nearly 370 agricultural polytechnics in which about 30% accommodate agricultural engineering schools. Approximately 9% of agricultural polytechnic students undertake agricultural engineering training. BAEU, which was founded in 1952 as the Beijing Institute of Agricultural Mechanisation, provides much of the training for teachers of agricultural engineering at these polytechnics. Today BAEU has a faculty of 650 including 174 professors and 269 lecturers. The university offers a 3-year diploma programme and a 4-year Bachelor's degree in agricultural engineering. Since 1980 it has provided at least 50% of all agricultural engineering postgraduates in the country.

According to Professor Wang, International co-operation has a high priority in BAEU. Contacts are maintained with more than 60 overseas universities and research institutions through which publications and technical information are exchanged. Recently new co-operative agreements have been formed with Britain, West Germany, Australia and Thailand. The British agreement is with Silsoe College. It began in 1985 and is assisted by a British Council link scheme support grant.

These developments are intended to support ambitious plans for growth in China, included in table 3. (Wan 1987).

Throughout the 60s and 70s the numbers of overseas students studying in Britain had been increasing steadily. In 1980, the full fees requirement was announced, which created much debate and prediction about declining overseas student numbers. In practice, this occurred in relatively few areas. Numerically, the effect on Third World agricultural engineering training in Britain was minimal. This was largely due to the willingness of aid agencies and overseas governments to increase the total funding for the subject, in view of its perceived importance to rural development. Some loss of goodwill has, however, been experienced. In the past few years student losses have been occurring. In a few cases, Third World countries have transferred agricultural engineering student applications en-bloc to the United States and to Australia. Full fee policies are, however, beginning to be introduced in those countries and elsewhere in the North. Professor

Table 3 China: Predicted growth

		1984	1990	2000
Total population	(millions)	1030.51	1105.79	1228.57
Rural population	(millions)	843	895.31	968.27
Rural labour	(millions)	359.67	385.38	410.26
Farm labour	(millions)	316.85	305.94	239.20
Cultivated area	(mil mu)	1479.38	1461.81	1436.84
Gross agricultural production	(bil yuan)	337.7	492	830.56
Rural enterprise production	(bil yuan)	96.06	198.50	492.50
Net income	(yuan per peasant)		461	745
Level of mechanisation	(per cent)		44.9	73.7

1 mu = 0.067 ha = 0.165 acre
1 yuan = £0.1436 Sterling (16th May 88)

Sims (1980), Vice-Chancellor of the University of Sheffield, predicted the loss of goodwill as a result of this policy will be substantial, whilst at home we will throw away tangible as well as sentimental benefits, for in economic terms it has always been apparent that the bonds formed by those who have studied in Britain frequently result in later trade benefits to the United Kingdom.'

A high value is placed upon both teaching and academic qualification in the Third World. Agricultural Engineering Study Fellows at Silsoe tell me that this is not only because both are recognised as the foundation of our profession, but because they offer measurable and attainable goals which, especially in the public sector, are used to determine salary level and career progression. Some senior students now argue that the expectations for teaching and qualification exceed their capacity to deliver in terms of job performance and in the sense of practical benefits to the community. They believe that the development of management skills has been seriously neglected. Values in teaching and research are now out of step with community needs. For example, they claim that the insistence on a doctorate as an essential level of attainment for university level teaching and institutional research should be reviewed. They suggest that this perpetuates a theoretically based academic system remote from society, its needs and its values. They remind me that we addressed a similar situation in Britain in the late 60s and the 70s and predict that many Third World countries might be doing the same in the late 80s and 90s.

What they would like to see is high academic standards, scholarship and the encouragement to generate new ideas, integrated with the acquisition of practical and management skills. This approach would be likely to develop the people so urgently needed to produce some realistic planning and action programmes in many fields, including agricultural engineering and food production. They believe that teaching programmes locally and in Britain for Third World students should reflect these ideas, at least until technical and management skills become recognised and accepted in their own right. Students at Silsoe point out that little is likely to change in their countries without strong support from government, encouragement and finance from the aid agencies and different criteria for career development, promotion opportunities and for the determination of salary level.

One method by which practical skills have been transferred successfully locally is through counterpart training. Such training may also include periods of full-time study abroad. Many agricultural engineering students have come to Silsoe in this way. Some were asked for their views on counterpart training.

One of the greatest benefits claimed for counterpart training was the personal contact with the expatriate Technical Co-operation (TC) adviser. In all cases the interest shown in counterpart training by the TC adviser was appreciated and recognised as an effective means of practical knowledge and skills transfer. Occasionally the TC adviser was recognised as a better professional agricultural engineer than trainer. 'How much training in training do the counterpart trainers receive?' asked one Study Fellow from Indonesia. Some problems were experienced by the counterparts in understanding why certain decisions were taken when the pressures of deadlines or funding limits prevailed. A Study Fellow from Ghana explained 'When the pressures are on, text book answers don't seem to apply. We can appreciate the need to improvise and think laterally, but the means by which this is done often does not get passed on. What the TC adviser doesn't always realise is that things change here when he has gone. I would not be able to implement decisions under exclusively local conditions that he made within the terms of an aid programme. How can the counterpart training experience deal with that?'

A Nigerian Study Fellow went on to remind me that courses at Silsoe — and possibly elsewhere — suffer from similar problems which can only be reduced by close professional contact between the teachers and the local jobs and working conditions of the Study Fellows. Local short courses, training and professional development might help in this respect. Other counterpart trainees from Africa drew attention to the movement towards development of the private sector locally and the use of 'private sector methods' by local governments. 'Will this mean that we will get more counterpart training in private sector methodology?' enquired a Study Fellow from Kenya. 'Most TC advisers that I have met are Civil Servants with little or no practical experience of working in the private sector. How will this problem be overcome?'

I did not have ready answers to these questions. The excellent practical work being undertaken in the Third World by British Agricultural College staff in practical training programmes is certainly a step in the right direction. Perhaps this can be developed in the future to involve more trainers with private sector experience, possibly through the BAETS initiative. (May 1988).

Professor Bonner (1979) suggested that 'It is increasingly recognised that new initiatives are needed to encourage overseas universities to take a more active role in identifying and investigating development problems. More emphasis on applied research and a little less on the academic research which has tended to dominate their outlook since their establishment, should now be the aim in higher education institutions of developing countries.'

Relatively little progress has so far been made with agricultural engineering research in Third World universities. Heavy commitments to teaching and limited funds are often quoted as the main reasons for this situation. This has important implications for attracting and retaining high-quality staff, for the introduction of postgraduate studies, for university contributions to farming communities and for the local development of the agricultural engineering profession. In the North several university departments have been concerned with practical research in connection with Third World agricultural engineering problems. Even from those universities relatively few ideas have reached the farmer.

Amongst the research institutes in Britain, two have contributed much to Third World agricultural engineering research, namely: the National Institute of Agricultural Engineering (NIAE) and the Tropical Development Research Institute (TDRI). (Now Agricultural and Food Research Council Institute for Engineering Research (AFRC IER) and Overseas Development Natural Resources Institute (ODNRI) respectively.)

Sidney Cox reported (1984) 'In the late 40s and early 50s many attempts to mechanise tropical agriculture failed because attention was paid only to the technical problems of the machinery. After the war, staff of the NIAE were involved in a number of projects to develop machinery for tropical crops. Recognition of the complex problems involved led first to the posting of a liaison officer of the Department of Technical Cooperation at NIAE in 1955. The post was assimilated to the Institute strength in 1958. Recruitment of other staff started in 1964 and in 1970 a small, special development section was added. In 1978 the unit was recognised as a Division of the NIAE. The Head of Division is also Agricultural Engineering Adviser to the Overseas Development Administration (ODA). Alongside this development, NIAE undertook the technical supervision of the East African Testing Unit which first became established in Kenya in 1956. (Manby 1961). Initial tests were concerned with power units and brush and scrub clearing equipment. The first drier tests at the unit were for pyrethrum driers, largely of local origin.

Much effort has been devoted by NIAE to improvement of implements for animal draught in collaboration with other Institutes in the UK and overseas. The Overseas Division has also been engaged in equipment development including a Banana Conveyor for the West Indies in 1973 and a Cotton-stalk Puller for Sudan in 1978.

During the 70s the emphasis of work in the Division changed from the development of equipment to the support and organisation of mechanisation systems in developing countries.

In the 80s a change in emphasis and some reduction in core funding prompted the Division to undertake some contract work for agencies other than ODA.'

In 1987 TDRI was renamed ODNRI in preparation for a move to new facilities at Chatham. TDRI was formed in 1983 from two units of the ODA, namely: the Tropical Products Institute (TPI) and the Centre for

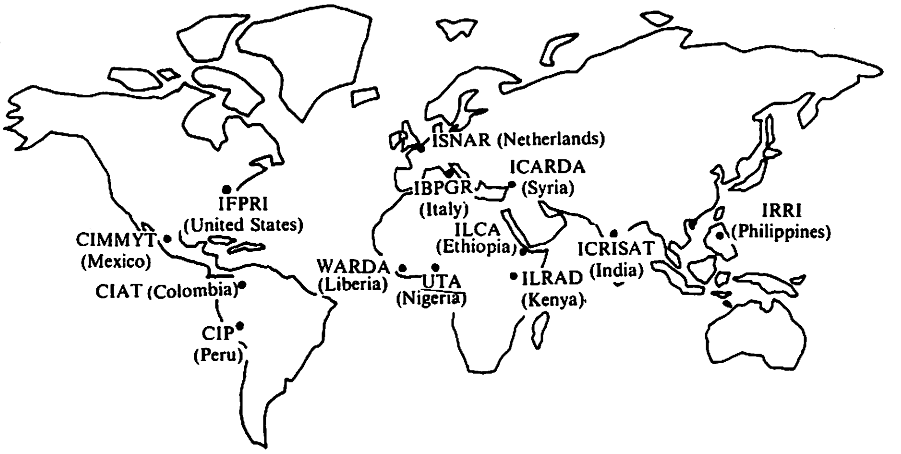


Figure 4 Global location of the 13 CGIAR-supported centers

Overseas Pest Research (COPR). TPI was formed in 1957 with origins dating back to 1894. COPR was formed in 1971 from a number of smaller units, the oldest of which was formed in 1929.

ODNRI also includes the Land Research Development Centre (LRDC). The function of ODNRI is to meet the needs of ODA's bilateral aid programme in the post-harvest area and to co-operate with developing countries in their efforts to derive greater benefit from their plant and animal products. It specialises in the various scientific, technological and economic problems that arise subsequent to harvest and is mainly concerned with such matters as processing, preservation, storage, transport, quality control, marketing, post-harvest economics and the use of wastes and by-products.

The Consultative Group on International Agricultural Research (CGIAR) was established in 1971. It is an association of countries, international and regional organisations and private foundations dedicated to supporting a system of agricultural research centres and programmes around the world. The purpose of the research effort is to improve the quantity and quality of food production in developing countries. There are thirteen supported centres, shown in Figure 4. Agricultural engineering features in all centres, but to varying degrees. At the International Rice Research Institute, for example, agricultural engineering has a prominent role with some 30 specialist staff working in the design, development, manufacture and use of machines in the Philippines and in many countries of the world through its outreach programmes. Agricultural Engineers at the International Institute of Tropical Agriculture have done some excellent work on the development of conservation tillage equipment. Ray Wijewardene in particular made some outstanding agricultural engineering contributions at IITA in the 70s. CIMMYT in Mexico, however, has no Agricultural Engineers although much of their work depends on precision field operations. ICRISAT has a local Sahelian Centre in Niger, but according to a personal communication from John Ashburner, is likely to close its agricultural engineering section in 1988.

Whether undertaken locally or elsewhere, priorities need to be established for research and development of agricultural machinery. Bell and Johnson (1986) have considered this. They argue for a systematic approach to the applied work supported by an 'adequate level of long-term fundamental research.'

Above all, agricultural engineers will need to ensure that their future research and development contributions are relevant and cost effective.

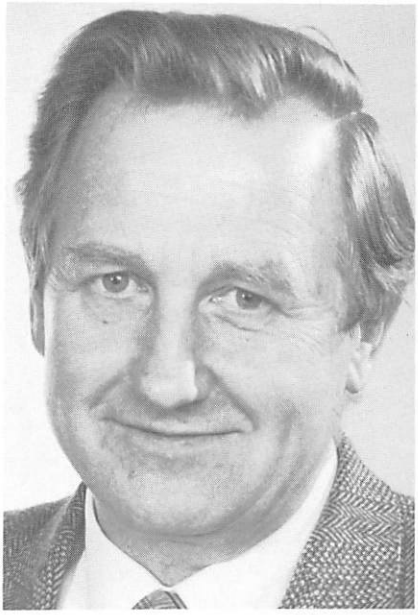
To be continued.

Near-ambient grain drying

M E Nellist

Summary

NEAR-AMBIENT drying in bulk grain stores is not the simple system that it might appear. Successful operation involves an understanding of the complex interaction of the many variables, particularly weather, which affect energy consumption, overdrying and spoilage. Computer simulation of the process has been invaluable in providing insight into their interactions and in making comparison of various contemporary operating systems, including the use of fans only, fans and heaters (electrical and gas), the use of off-peak (Economy 7) power and heat pump dehumidifiers. The limitations of such studies are that the systems are not necessarily optimum and, if they were, their application in practice would depend upon more sophisticated decision-making than is possible with present combinations of instrumentation and operator expertise. The quantification and detection of grain spoilage is also unsatisfactory. The objectives of current research are to identify optimum strategies and to develop means of applying them on a short term tactical basis on a real drier by the use of microprocessor controllers.



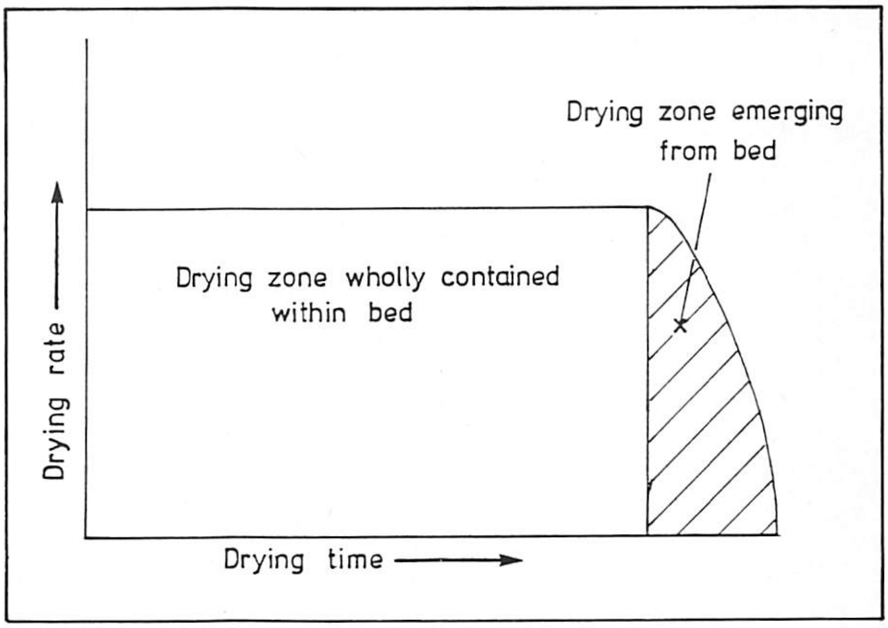
1 Introduction

Near-ambient drying is the drying of grain in deep layers with large volumes of air of which the evaporative capacity is largely determined by its existing content of solar heat. Thus the main use of supplied energy is to drive the fan forcing the air through the grain. By being converted into heat, some of this energy adds to the drying capacity of the air; if necessary, a further increase in drying capacity or reduction in relative humidity can be achieved by conditioning the air either by additional heating or by dehumidification.

For near-ambient drying to be economic it is essential to maximise the use of the very limited drying capacity of air at near-ambient temperatures by retaining the drying zone within the grain bed for as great a proportion of total drying time as possible (Fig 1), but not so long that, or under conditions in which, the undried grain in contact with the near-saturated exhaust air deteriorates whilst the already dried grain becomes too dry. Typically the method will work for beds of grain between 1½ and 4 m deep for ambient air raised not more than 5°C at flows of about 50 $dm^3\ s^{-1}\ t^{-1}$, and for drying times of the order of 5 to 30 days. Optimum bed depths and airflows depend upon a number of factors of which the most important are the initial moisture content and pressure resistance characteristics of the grain and duct system, the pressure and volume characteristics of the fan or fans and the desired final condition of the grain. But most important of all is the overall level of ambient temperature and relative humidity, its diurnal variation and the extent to which it can be controlled either by selective switching of the fan(s) or judicious use of heating or dehumidification.

The interactions of these factors are so complex that it is not possible to formulate any simple rules by which to determine the optimum combinations or to maintain optimum conditions throughout the drying history of a particular batch of grain. Uncontrollable variation in

Fig 1 In near-ambient drying, the drying zone must remain within the grain bed for the major proportion of the drying time



Martin Nellist is Head of the Crop Drying Department at AFRC Engineering, Silsoe, Bedford.

the weather and grain and the slowness of the process also prohibit systematic analysis by physical experiment alone.

However, the drying process obeys the laws of physics and can be modelled mathematically provided that the necessary drying properties of the grain are known. Furthermore, if safe storage times in relation to grain temperature and humidity are known, an estimate of the rate of deterioration of the grain can even be derived. Thus, computer models of near ambient drying have been developed and have been used in simulated experiments to study the effect of variation in individual factors when others are held constant. In the UK, models of near-ambient drying have been developed at AFRC Engineering (Sharp, 1983; Brook, 1987), and SIAE (Bowden et al, 1983; Smith & Bailey, 1983) and used to analyse and compare various possible strategies for operating near-ambient driers under typical weather conditions as represented by historical data. Valuable as these studies have undoubtedly been, none have sought to determine optimum policies for operating systems for switching and regulating fans and heaters.

The purpose of this paper is to explore the underlying interactions determining the success or otherwise of drying with near-ambient air and to explain how contemporary research is attempting firstly to identify optimum operating strategies, and secondly to apply them in a day by day, or hour by hour, tactical sense through the more sophisticated use of microprocessor controllers.

2 Components of cost

Ultimately, the success or otherwise of the drying is measured by its cost. In this paper, we are concerned not with what equipment to buy but how to operate those combinations of equipment it is possible to buy. We are concerned, therefore, solely with running cost and not with capital cost. Consideration of the latter is vital if an investment decision is to be made, but no longer relevant after the equipment has been purchased.

It is relatively easy to identify the major components of running costs as being those of energy supplied and the loss of revenue from overdrying and grain spoilage if any. Energy costs and overdrying costs are relatively straightforward and are explained further by Fig 2. In this diagram it is assumed that drying may be from as high a moisture content as 26%, and that the target moisture content is 15%. Then, depending upon the efficiency of evaporation and/or the cost of energy, the cost of removal of water is directly proportional to the initial moisture content. The lowest cost curve on the right-hand side of Fig 2 is calculated for a specific energy consumption of 3 MJ/kg water evaporated and an energy cost of 1.5 p/kWh. Successively steeper curves represent either increased specific energy consumption or increased energy cost. More often than not it is necessary to dry to a mean moisture content less than 15% if some part of the grain-bed is not to be left at an undesirably high moisture content. This overdrying represents a cost in two ways. Firstly, there is the additional energy required to do it and, assuming a constant specific energy consumption, this can be represented by similar lines to those showing the drying cost. But, in addition, there is the opportunity cost of the water that under many trading arrangements could have been sold as grain. On the assumption that this grain might be worth around £100/t, Fig 2 shows that this lost weight is a far more important consequence of overdrying than the additional energy required for evaporation.

Less easily defined or quantified is the cost of any loss in value due to deterioration caused by microbial or other biological metabolisms. Fig 3 shows that on the assumption that the consumption of dry matter is an inescapable consequence of this metabolism, then at the very least there will be a cost proportional to the loss of weight. At some point, however, this deterioration reaches a level at which it renders the grain more or less worthless, and the spoilage cost rises to what would otherwise have been the market value of the grain. In Fig 3 this rise is shown as occurring at a dry matter loss of 0.5% at which point it might possibly be equated with the appearance of visible mould. In fact there is no

Fig 2 Effect of specific energy consumption (MJ/kg) and energy cost (p/k Wh) on drying cost and of overdrying on lost revenue

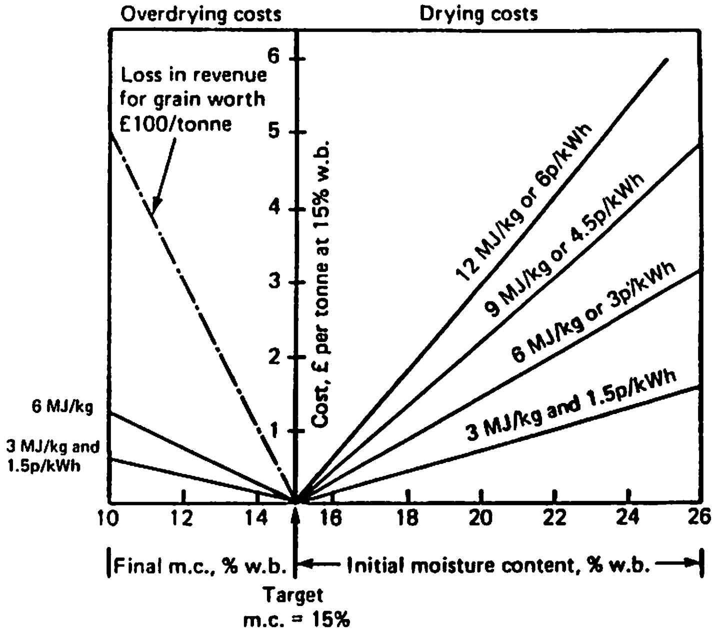
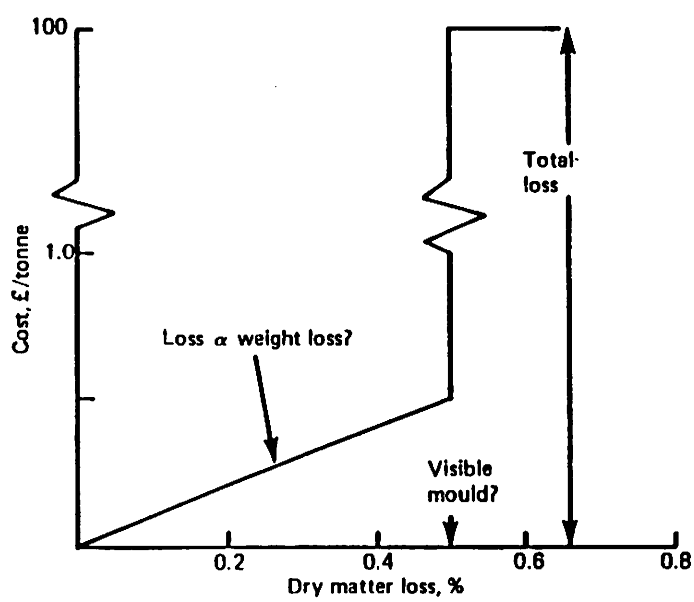


Fig 3 Cost of spoilage as a function of dry matter loss and indicating total loss above 0.5%, a level at which mould might become visible



evidence to define the level of dry matter loss which equates to visible mould and 'visible mould' is itself an imprecise definition. It might also be argued that the real value of the grain has declined well before it becomes visibly mouldy so that the spoilage cost curve should run at a higher level than that shown. Sadly, however, the difficulty of rapidly detecting mould growth allows much mouldy grain to be marketed as sound, and even clearly unsound grain commands a price although perhaps no more than say £20/t.

3 Quantifying spoilage

Although mould may be difficult to detect in grain cleaned for sale, and may not incur a cost penalty in many transactions, researchers can hardly develop, and advisers can hardly recommend, drying policies which allow mould growth. Although it may not yet be possible to add spoilage to the cost function, it is necessary to attempt to define levels of spoilage within which acceptable drying policies must be contained.

Ideally these levels would be defined as we have seen by ascertaining levels of dry matter loss and associated production of water, carbon dioxide and heat, resulting from respiration. Unfortunately, data on the respiration of grain is meagre and conflicting, and it is conventional to fall back on the 'visible mould' concept by using data defining 'allowable storage times' before the occurrence of 'visible mould'. The original data were suggested by Kreyger (1972), Fig 4, and are embodied in various guises in much official and commercial advisory literature. More recently for use in computer simulations, Kreyger's data have been expressed in functional form (Bowden et al, 1983) and in one case combined with additional data (Frazer & Muir, 1981).

But how can these steady-state times be applied to the unsteady-state conditions which grain experiences during drying? A method which has been widely used by many researchers, including ourselves at

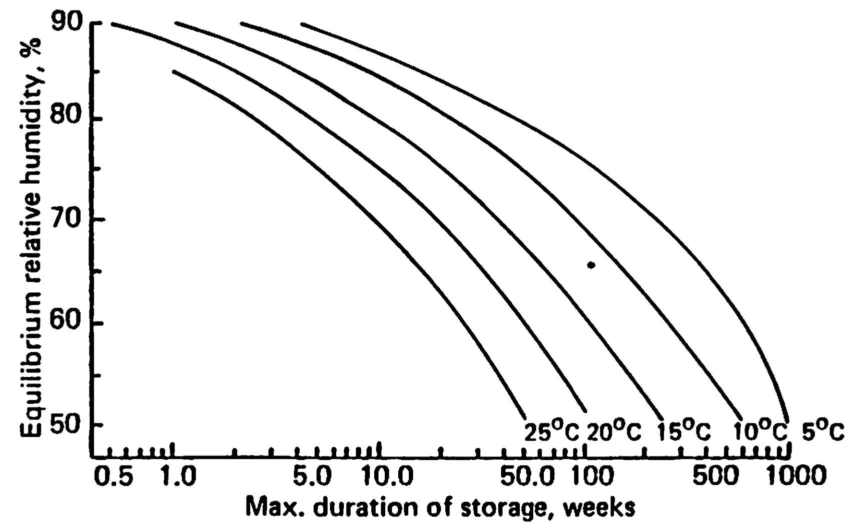


Fig 4 Effect of equalibrium relative humidity and temperature on maximum duration of storage on barley and rape. (Derived from data of Kreyger, 1972)

Fig 5 Computed effect of constant ambient temperatures and relative humidities on the airflow required for drying by continuous ventilation a 2.5 m bed of wheat initially at 20% m.c.w.b. Final moisture requirements were ≮ 15% for the mean of the bed and ≮ 16.5% for the wettest layer. Total drying times and maximum spoilage index could not exceed 18 days and unity respectively

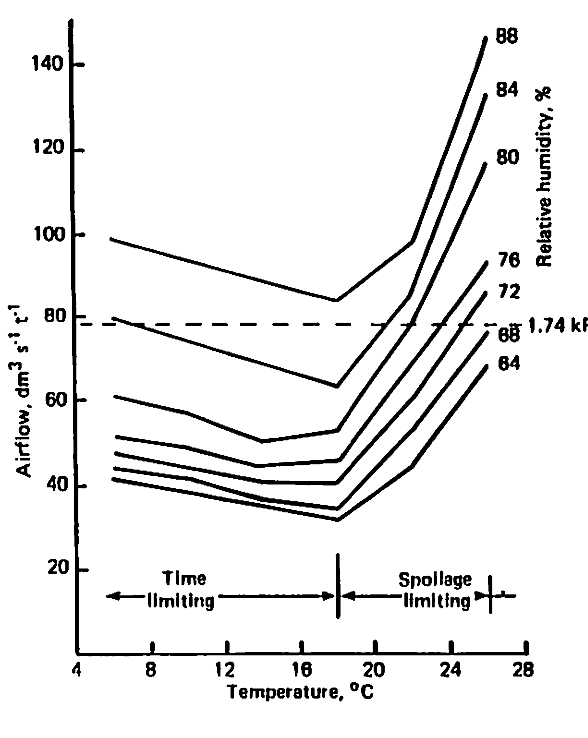
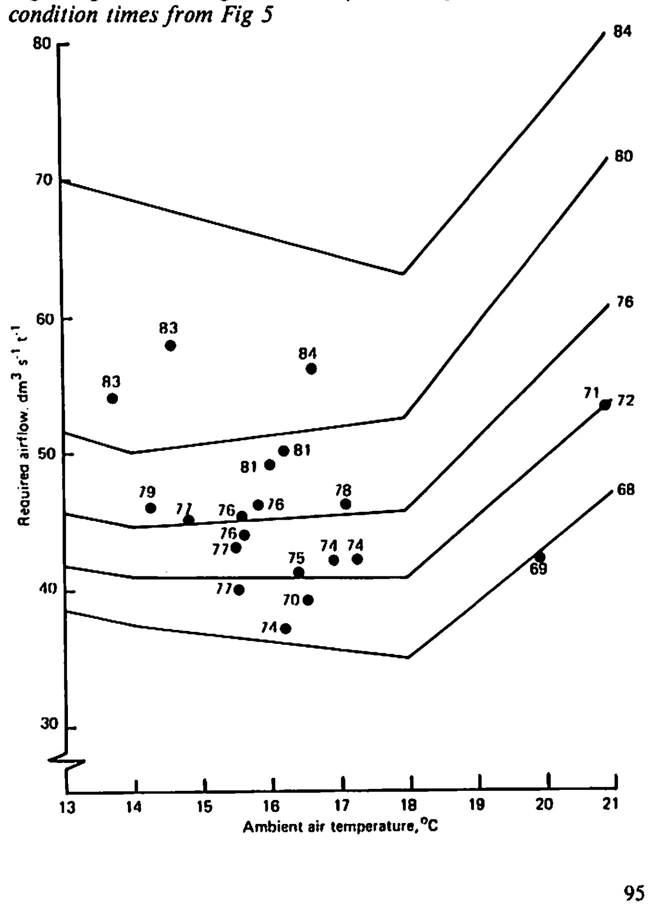


Fig 6 Computed effect of average ambient temperatures and relative humidities, (values denoted at each point) for drying by continuous ventilation during 20 separate years at Heathrow beginning on 15th August in each year, compared with constant condition times from Fig 5



AFRC Engineering, is to assume that at any one combination of temperature and moisture content, the rate of spoilage is linear. Then the fraction of the total allowable storage time that is used up during a short period at constant conditions is that period divided by the total allowable time for those conditions. If similar fractions are calculated for successive short periods, then, when the sum of these fractions attains unity, the allowable storage time may be regarded as used up. Now, of course, this is a gross over-simplification and desperately needs replacing with a better method of integrating metabolic activity, but its continued use is justified because (a) we do not have a better method, and (b) the results do tend to give answers which are realistic and, if anything, err safely on the conservative side.

4 Air flow — quantity and quality

In reality, the operation of a near-ambient drier is concerned with either taking advantage of, or modifying, the continual variation in ambient temperature and relative humidity. However, as a starting point for discussion it is convenient to consider the much simpler case of drying by continuous ventilation with air at a constant temperature and humidity. Fig 5 was derived using the computer simulation, STOREDRY, (Brook 1986, Hodges et al, 1988) to find airflows necessary to dry a 2.5 m bed of wheat from 20 to 15% m.c. in not more than 18 days and without exceeding a spoilage index of unity in the wettest layer of grain. In addition, for drying to be complete, that wettest layer had also to be 16.5% m.c. or less. In calculating the drying effect of the ambient conditions depicted in Fig 5, STOREDRY takes into account the temperature rise which would result from a fan of an assumed 50% efficiency, pumping air against the combined pressure resistance of a typical duct system and 2.5 m depth of wheat.

It can be seen that at any given temperature, the effect of increasing the relative humidity is to increase the quantity of air required. Not surprisingly also, the initial effect of increasing temperature at a given relative humidity is to reduce the airflow required since this increases the drying capacity. However, the perhaps unexpected effect is that at temperatures above 18°C, more, not less, air is required. Although the drying capacity of the air continues to increase, the rate of deterioration of the grain increases at an even greater rate and drying has to be completed in less than 18 days if 'visible mould' is not to be predicted. Thus, for a 2.5 m bed being dried from 20 to 15% within 18 days and without spoilage, there appears to be an optimum ambient temperature of 18°C at which the required airflow is a minimum irrespective of the value of ambient relative humidity. Note however that the minimum will not necessarily be the same for other bed depths, moisture removals and drying times. Note also the dotted horizontal line in Fig 5 denoting a fan static pressure of 1.74 kPa and representing the upper limit for most agricultural fans. Thus it would be impractical to consider airflows in excess of around 78 $dm^3 s^{-1} t^{-1}$.

It should now be clear that even without the problem of seasonal and diurnal variation in weather, the interactions of the other variables are complex.

5 Weather, depth and initial moisture content

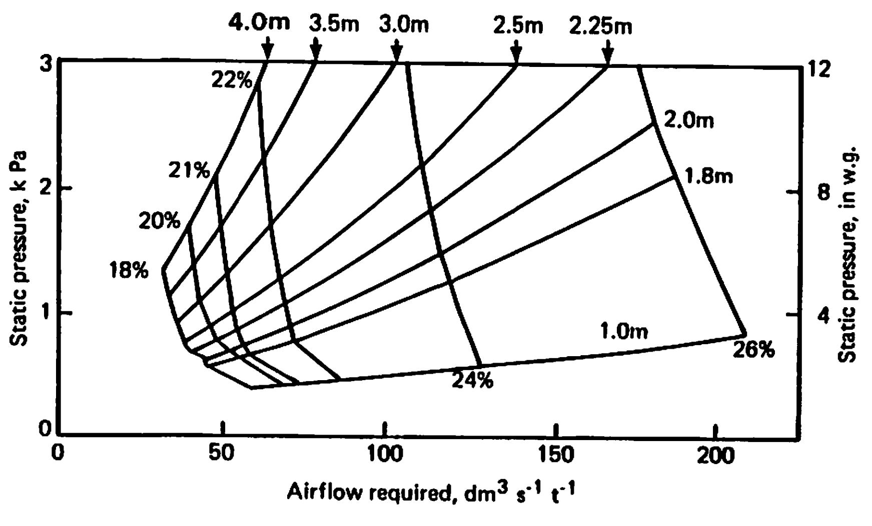
In a more complex study of continuous ventilation (Nellist & Brook, 1987), seasonal and diurnal variations in temperature and relative humidity were obtained from historical records for Heathrow (London) for 20 years (1951–1970). Drying was assumed to start on the 15 August of each year. Once again the computer simulation searched for the airflow required (a) to dry to moisture contents of 15% and 16.5% for the bed mean and wettest layer moisture contents respectively, and (b) to dry within 18 days or less without exceeding the spoilage index of unity.

In addition, this study considered the effect of bed depth (from 1–4 m), and initial moisture content of the grain (from 18–26%). One of the combinations of initial moisture content and depth was 20% and 2.5 m, and in Fig 6 the airflows required for each of the 20 years are plotted against the average ambient temperatures during drying in those years. The average relative humidity for the year is indicated against each point.

By themselves the 20 points do not suggest much of a relationship between the required airflow and average ambient conditions. However, when the appropriate portions of the lines for constant conditions from Fig 5 are included, it can be seen that the results do fit into the general framework provided by those lines. The fact that they do not follow it exactly confirms that weather variations have a significant effect which precludes the use of average conditions for other than approximate calculations.

For similar reasons it is not really desirable to average results over 20 years, but it is convenient to do this to discuss the general effect of bed depth and initial moisture content on the airflow required. Fig 7 shows the variation in airflow required and static pressure with the indicated combinations of bed depth and moisture content. The effect of increasing moisture content is, not

Fig 7 Average effect of grain initial moisture contant and bed depth on the static pressure and airflow required to complete drying by continuous ventilation at Heathrow commencing 15th August for the 20 years, 1951–1970



surprisingly, to increase the airflow required per tonne and therefore increase the pressure required. Increasing the bed depth causes a disproportionate increase in pressure because of the increase in air velocity needed to sustain a given airflow per unit weight. This also increases the air temperature and hence drying capacity so that for any given moisture content, the airflow required reduces slightly with depth. By interpolation from Fig 7 it is possible to construct Fig 8 to show the variation in bed depth and mass of grain that can be dried per unit volume of air at static pressures from 0.5 to 1.74 kPa. Within this pressure range, which is that of most agricultural fans, it is feasible to vary bed depths from 1.5m to 4.6m at 18%m.c. but only from 0.5 m to 1.6 m at 26% m.c. Also, at 1.74 kPa the mass of grain which can be dried by a cubic metre of air, reduces from 32.5 tonnes at 18%m.c to 5.3 tonnes at 26% m.c.—a factor of 6. To illustrate how this very large change can affect drier capacity it is necessary also to consider the way the volume delivered by the fan is affected by the bed depth. In Fig 9 the data of Fig 8 has been combined with the pressure/volume characteristic of a typical 75 hp centrifugal fan to produce a chart showing the number of tonnes dried by the fan at various combinations of bed depth, static pressure and initial moisture content. This shows very clearly that because of the reduction in delivery volume with increasing pressure, there is an optimum pressure of approximately 0.75 kPa at which the fan is capable of drying the most grain.

This, of course, assumes that the drier is loaded instantly and only used once; it does not take into account drying times and the possibility of multiple loading or of the way in which a real drier will be filled over a period of days or even weeks. It also assumes continuous ventilation. So this provides no more than a rough guide, for instance, in sizing of fan for a storage drier. It does illustrate however the factors that need to be considered.

6 Drier control

6.1 Experiments by computer

Although there may be some operators who use a fan only and ventilate continuously throughout the drying period, the majority prefer to exert some form of control over the drying either by running the fan only during favourable weather conditions, or by increasing the drying capacity of the air, either by additional heating or by dehumidification. Whatever policy is adopted the control actions are normally taken either directly or indirectly in response to changes in the relative humidity of the air. There are a number or proprietary controllers which are capable of switching fans and heaters at pre-set levels of relative humidity and, with the introduction of microprocessors, some of these can utilize multiple setpoints. On the whole, however, the processing power of such controllers is under-used. This is partly because of the inaccuracies of humidity sensors, but more because control policies implemented are based on fairly simple rules of thumb.

It was to attempt to understand and improve rule of thumb drying strategies that computer simulations if near-ambient drying were developed (Sharp, 1982). So far the emphasis has been on examining the effects of the major variables on the performance of existing simple systems and making comparisons between them. A better approach is outlined at the conclusion of this paper, but this is not to discount the value of these earlier studies. Worldwide, there have been a great many, but the author, being unashamedly parochial, has used examples from the UK (see Table 1).

Sharp (1984), using the original version of STOREDRY in a study of the effect of initial moisture, grain depth, fan power and geographical location, considered four ways of controlling a fan-only system. These were to switch the fan off whenever the relative humidity of the drying (plenum) air exceeded:—

(1) a pre-set value;
(2) the equilibrium relative humidity of the wettest layer;
(3) a pre-set value until the drying front broke through the surface. After that the fan would be run only if the drying air relative humidity fell within the range set by the equilibrium relative humidities of the target

Fig 8 Average effect of grain initial moisture content and fan static pressure on the necessary bed depth and the quantity of grain dried per unit volume of air derived from Fig 7

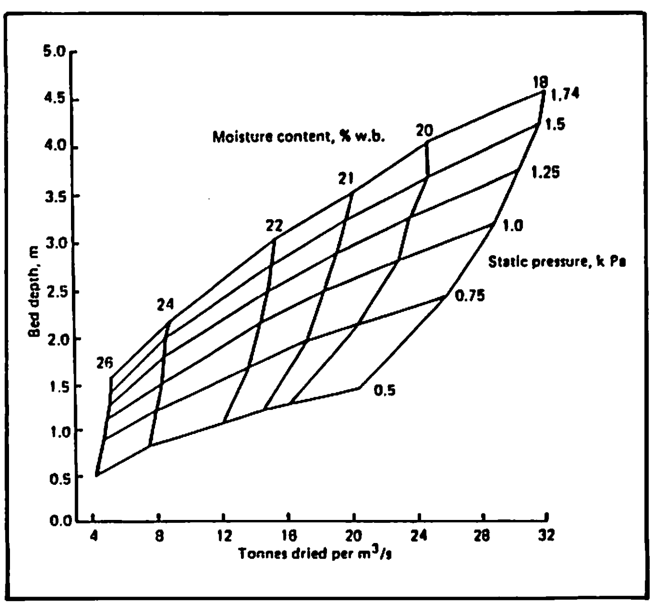


Fig 9 Average effect of grain initial moisture content and fan static pressure on the necessary bed depth and the quantity of grain dried by a typical 75 hp centrifugal fan for the data of Fig 8

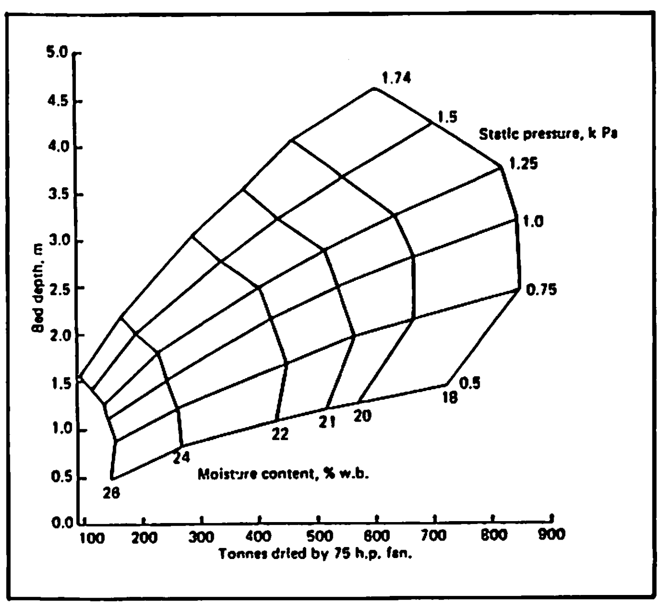


Table 1 Comparison of factors and criteria used in simulated drying experiments for UK conditions

Author(s)	Smith & Bailey (1983)	Sharp (1984)	Brook (1987)	Nellist & Brook (1987)	Nellist & Bartlett (1988)
Grain	Barley	Wheat	Wheat	Wheat	Wheat
Initial moisture contents, % w.b.	20	19–20.5	18–24	18–26	20
Bed depth, m	3.0	2.0–4.0	3.0	1.0–4.0	3
Airflow, $dm^3s^{-1}t^{-1}$	46.5	46–91	47–107	—	27–79
Heater power, W/m^2	400;800	—	2 x fan power	—	328–730 798–1596
Weather					
Location(s)	Turnhouse	5 in England	Heathrow	Heathrow	Waddington
Years (No.)	1968–1972(5)	1951–1970(20)	1961–1970(10)	1951–1970(20)	1951–1970(20)
Start date	15 Aug	15 Aug	1 Sept	15 Aug	15 Sept
Limiting conditions					
Drying time, days	—	<50	<14	<18	<62
Spoilage*	—	—	<1.0	<1.0	—
Target criteria					
Final moisture content, % w.b.	—	15.5	14–16	15	15
Wettest layer m.c., % w.b.	—	16	14–16	16.5	16
Grain temperature, deg C	10	—	—	—	—

**See paragraph 3 – Quantifying spoilage*

moisture contents for the bed and for wettest layer. This was an attempt to minimise the overdrying of the bottom layers.

The fourth method was simply to switch the fan off between 21.00 h and 06.00 h each night. This method was the worst on all counts; the extended residence times led to high spoilage, and the daytime ventilation ensured high overdrying.

The results for the first two methods showed that control of the fan by humidistat could lead to savings in energy nevertheless, because over-drying costs were of a similar magnitude to the drying costs, slight savings in energy consumption might be more than outweighed by lost income through over-drying. The strategy of modifying the relative humidity setpoint, by reference to the target equilibrium relative humidities once the drying front had broken through the surface, achieved the aim of reducing over-drying and gave the lowest total costs in good and bad years. However, it is difficult to compare the strategies without some overall formula which weights the energy consumption, the overdrying and the spoilage, and Sharp himself noted that the combinations of setpoints, airflows and other factors were not necessarily optimum.

The results for the effect of depth and weather variation were consistent with the trends already examined in Section 5. Thus, for example, the rate of spoilage was greater and hence minimum airflow requirements were higher at Heathrow (London) than at cooler, wetter Manchester. Increasing bed depth at the same airflow led to steep rises in energy consumption and increased risk of spoilage. Conversely, increasing airflow at the same bed depth decreased the risk of spoilage with little increase in energy consumption but with more overdrying.

A study by Smith and Bailey (1983) of the drying of barley under Scottish conditions, was confined to a single initial moisture content (20%), bed depth of 3.0 m and airflow of 46.5 $dm^3s^{-1}t^{-1}$ but, as well as fan control considered strategies for using supplementary heat. There were two fan control strategies. The first was identical to that of Sharp (1984) in which the plenum relative humidity was compared against a pre-set value. In the second, the instantaneous plenum relative humidity was replaced by the average relative humidity of the air blown through the grain since the start of drying. Presumably the idea was to adjust for the specific year and dampen response to short term variation in relative humidity.

There were three strategies for the use of supplementary heat. In the simplest case, the complete heater load of 400 W/m^2 or 800 W/m^2 was switched on when, after passing through the fan, the relative humidity of the air exceeded a pre-set value. In the second method the instantaneous plenum relative humidity was replaced by the average value for the air blown from the commencement of drying. In the third, the heat was modulated up to the maximum available, either 400 W/m^2 or 800 W/m^2, so that the relative humidity of the drying air from the commencement of drying was maintained at a constant value.

Major differences between this work and that of Sharp (1984) were the criteria for the completion of drying. Smith and Bailey (1983) ceased drying once the drying front broke through the bed surface. Thereafter the fan was run only when the duct temperature was less than the average bed temperature and the duct relative humidity was less than 75%. This cooling was stopped when the average temperature in the grain bed was less than 10°C. Thus the endpoint was a temperature not a moisture content.

The main conclusions were that drying with fan control used less energy than drying with supplementary heat, but that in some years it was necessary to use some heat to reach moisture contents of less than 14.5% There was more risk of loss of viability and mould growth from delayed drying by fan control than from the higher temperatures resulting from supplementary heat. These results are consistent (Fig 5) with comparative cold weather conditions as might be expected for Scotland. Using the long term average relative humidity to control a fan and heater, or using a modulating heater control, gave better ability to select the final moisture content but did not improve the energy consumption or lessen the risk of spoilage. Cooling the grain did lessen the risk of spoilage.

Yet another approach was taken by Brook (1987) who used STOREDRY to compare single setpoint and multiple setpoint control of the fans and of the heaters for the 3 m bed of wheat, and using 10 years of the Heathrow (London) weather data used by Sharp (1984). Four initial moisture contents (18,20, 22 and 24%) and two final mean bed moisture contents (14 and 16%) were included. The novelty in the approach was the concept of determining for each moisture level the airflow which dried to 16% with a spoilage not exceeding unity and in not more than 14 days of continuous ventilation. For any one moisture level, the average of these airflows divided the ten years into 'favourable' and 'unfavourable' years. Then fan control strategies were tested on the 'favourable' years and heater control strategies on the 'unfavourable' years. This simple division ignores the non-linear effect on the required airflows caused by the use of both a drying time and a spoilage level as limits to successful drying, i.e. the effect illustrated by Fig 5. Thus, for example, the use of heat in some unfavourable years might be counter-productive in terms of increased spoilage. But Brook did also proceed to determine the best strategy for individual years. Overall, his conclusions were that fan control was generally more economic than heater control in 'favourable' years, but in certain years, heater control gave similar energy consumption. These may have been 'time-limiting' years. Conversely, when drying from 22% in two of the years, neither fan nor heater control at the average airflow could prevent spoilage. For both fan and heater control, relative humidity set points were in the range 75–85% depending upon the difference between the airflow used and that indicated as required for continuous ventilation.

Brook also considered two possible strategies for controlling by reference to drying rate. In the first, for fan control only, the fan would be switched off if the net moisture removal from the grain was less than zero. While reducing energy consumption, this method increased overdrying since it prevented rewetting of overdried bottom layers. For applying this 'rate error' approach to heater control it was necessary, by equating drying rate to spoilage rate, to calculate a temperature rise which would accelerate drying without excessive spoilage. This system did not improve upon single set-point heater control. Nor did yet another method which was based upon optimising a linearised system but Brook was unable to do more than a preliminary foundation for this.

In another study Brook (1986) demonstrated the use of the model to carry out a feasibility study on the use of a heat-pump dehumidifier for near ambient drying. This work quantified the technical advantages of such equipment and provided a guide to the level of capital investment that could be justified.

The model of the dehumidifier was used subsequently in a study (Nellist & Bartlett, 1988) of 8 possible control strategies for a drier situated in an unfavourable location (Waddington, Lincolnshire) and operating at an unfavourable time of the year, i.e. drying commencing on 15 September. Because the study arose from the joint initiative of ADAS and the Electricity Council, it was based upon commercially available equipment and included an evaluation of the use of Economy 7 electrical power. Of the 8 methods, 6 were based upon the use of a microprocessor-controller which was assumed to be capable of using 4 relative humidity set-points determined by reference to the moisture content of the wettest layer. The controller provided three possible modes of control; (1) fan control, (2) staged heating to modulate relative humidity or just below set-point and (3) staged heating to modulate relative humidity at 62% once switched. Fan control was compared with fan control plus staged heating in off-peak periods and with staged heating in both on- and off-peak periods. Simulations were repeated at 3 levels of airflow typical of ADAS recommendations, and for the 20 years, 1951–1970. For the two treatments without supplementary heat, i.e. continuous ventilation and fan control only, an additional higher airflow was necessary to complete drying in all 20 years.

Table 2 presents some examples of results averaged over the 20 years and selected on the basis of similar average spoilage indices and at airflow levels for each method ensuring completion of drying in all years.

The main conclusions from the study were that to complete drying with a broadly similar degree of spoilage:

(a) The dehumidifier used least energy and the lowest airflow but, as modelled, the overdrying was excessive.
(b) Compared with continuous ventilation, fan control reduced energy consumption and year-to-year variation but increased overdrying.
(c) The combination of fan control on-peak with staged heating off-peak gave similar energy consumption to fan control only but, because of the Economy 7 tariff, was cheaper.
(d) Excessive use of staged heat, as in control mode (3) gave high energy consumption and high overdrying.

6.2 Optimum strategies

All of these studies have provided far more insight into the operation of near-ambient driers than could have been obtained by physical experiment alone but even the computer experiments are inadequate in the range of variables that they explore. But it is clear also that this sort of computer experimentation has served its purpose. There is not much to be gained by making further comparisons of strategies which are not optimum and which are examined by the computer on the basis for example: that the relative humidity of the air is known or can be measured accurately, that the initial moisture content to the grain is uniform and the drier filled instantaneously, or that the location and moisture content in the wettest layer is known or can be sensed. We now have to find ways of identifying optimum strategies and of applying them to the operation of real driers on a short-term tactical basis

Table 2 Example results from the study by Nellist and Bartlett (1988) averaged over 20 years and selected on the basis of similar spoilage. Note reduction in airflow from continuous ventilation through to dehumidifer

Policy	Continuous ventilation	Fan control only	Fan control plus staged heating			Staged heating		Dehumidifier
			Level 1	Level 2	Level 1	Level 1 (Propane)	Levels 1 & 2	
Airflow, dm^{3}s t^{-1}	74.00	74.00	53.20	49.20	49.20	49.20	49.20	34.00
Spoilage index	0.48	0.53	0.75	0.72	0.74	0.74	0.65	0.75
Drying time, days	12.0	14.6	23.0	10.5	21.8	21.1	16.8	20.3
Energy consumption, MJ/t dried								
Fan On-peak	161	157	106	76	109	107	85	45
Off-peak	68	53	61	42	46	45	36	19
Heater On-peak	0	0	0	0	37	40L	19L	37L
Off-peak	0	0	37	137	32	36	118	16
Total	229	210	205	255	223	228	258	117
(Minimum)	181	171	133	174	132	133	189	108
(Maximum)	338	268	284	322	324	319	328	126
Coefficient of variation, %	19.6	13.5	19.6	13.6	24.5	23.8	14.2	4.0
Cost, £/t dried								
Energy	2.80	2.65	2.13	2.10	2.61	2.22	2.39	1.43
Overdrying	0.66	1.16	0.58	1.42	0.43	0.52	1.15	2.02
Total	3.46	3.81	2.71	3.52	3.04	2.74	3.54	3.45

Assumed tariffs for on-peak and off-peak (Economy 7) electricity and for propane heat are respectively 5.45, 1.90 and 1.76 p/kWh. For overdrying, grain costed at £100/t.

appropriate to the particular conditions of grain type, moisture content and weather.

Work on both aspects is in progress at AFRC Engineering. Currently we are attempting to optimise an algorithm, similar to that proposed by Ryniecki (1985) and reviewed by Rumatowski and Ryniecki (1986), for a system of fan and heater control in which it is assumed that (i) the optimum airflow during fan only periods may be different from that required when heat is being used, (ii) the heat can be applied in 10 equal increments, and (iii) the relative humidity set-point can be adjusted in relation to the progress of drying in the bed. The parameters of this policy are the airflows in heating and non-heating phases, the heater power and the dependence of the relative humidity set-points (one for switching between heat and no-heat and one for controlling the relative humidity of the heated air) on one or more measures of the progress of drying, e.g. the average moisture content and the moisture content of the wettest layer or the moisture content of the layer of maximum evaporation.

This work is proceeding well and we have every confidence that we can reduce energy consumption to levels similar to those of the dehumidifier and yet avoid overdrying. One factor which has emerged is that seasonal variation in relative humidity effects overdrying more than it does energy consumption and that selection of the correct set-point parameters for a particular year is improved if the overall level of relative humidity is known. The indications are that the average relative humidity over the three weeks prior to the start of drying provides a good guide to the initial setting of these parameters. In practice this might mean that an operator or the controller itself would need access to local weather data at least three weeks before the expected start of drying.

Another aspect of applying the algorithm in practice is the difficulty of measuring relative humidity of the air accurately and of measuring grain moisture content at all. Here we are attempting to use the drying model to either improve a measurement or infer the value we need from other measurements. For example, in simulated experiments we have found that, given measurements of several temperatures within the grain bed, we can use the model to predict moisture contents through the bed even if our initial estimate of the moisture profile through the bed is incorrect. Fortunately, because of the slowness of near-ambient drying, there will be no problem in putting a complete model into a micro-processor-controller for use in this 'inferential' or adapture manner.

7 Conclusions

7.1 The sucess of near-ambient drying depends upon minimizing energy consumption and overdrying without allowing the grain to deteriorate.

7.2 At near-ambient temperatures, moulding is the most important form of deterioration but the kinetics of mould growth are not yet understood and only approximate estimates of spoilage are possible. Commercial valuation of the cost of spoilage depends upon the development of rapid methods of detecting and quantifying non-visible mould.

7.3 Whilst there are opportunities for reduction, the energy consumption of successful near-ambient systems is as low or lower than the best heated-air systems. Unsuccessful operation can lead to extremely high energy cost and loss in crop value.

7.4 Computer simulation of near-ambient systems has provided insight into factors affecting operation but has not yet identified optimum methods of operation. Generalised conclusions are that:—

(a) Some form of control, even if only of a fan, is needed.

(b) In most years some form of air conditioning is necessary of beneficial but, to avoid overdrying, must be used with care. Air conditioning by heating is best in cool years; in warm years it may accelerate spoilage faster than drying.

(c) Bed depth needs to be altered in relation to grain moisture content and to the pressure/volume characteristics of the fan.

7.5 The objectives of ongoing research are to identify optimum operating strategies and to apply them in a tactical sense through the better programming of microprocessor-controllers.

Acknowledgement

My thanks to recent collaborators Dr Roger Brook, Dr David Parsons, Tim Hodges, David Bartlett and Dr Antoni Ryniecki.

References

Bowden P J, Lamond W J, Smith E A (1983). Simulation of near-ambient grain drying I. Comparison of simulations with experimental results. *J agric Engng Res,* 18, (4) 279–300.

Brook R C (1986). Heat pumps for near-ambient grain drying: a performance and economics feasibility study. *Agric Engr,* 41,(2), 52–57.

Brook R C (1987). Control system development for near-ambient grain drying AFRC Inst Engng Res, Silsoe, Div Note DN 104.

Brook R C (1987). User's guide to the IER near-ambient grain drying model, AFRC Inst Engng Res, Silsoe, Div Note DN 1384.

Frazer B M, Muir W E (1981). Airflow requirements predicted for drying grain with ambient and solar-heated air in Canada. *Trans Am Soc agric Engrs,* 81, (24), 208–210.

Hodges T P, Bartlett D I, Nellist M E (1988). Supplement to the User's Guide to the AFRC Engineering near-ambient grain drying model. AFRC Inst Engng Res, Silsoe, Div Note DN 1458.

Kreyger J (1972). Drying and storing grains, seeds and pulses in temperate climates. Inst Voor Bewaring En Verwverking Van Landbouwprodukten. Pub. 205.

Nellist M E, Bartlett D I (1981). A comparison of fan and heater control policies for near-ambient drying. AFRC Inst Engng Res, Silsoe, Report No 54.

Nellist M E, Brook R C (1988). Drying wheat by continuous ventilation with unheated air in a favourable location. AFRC Inst Engng Res, Silsoe, Report No 51.

Rumatowski K, Ryniecki A (1986). Application of microprocessor programmer to control low-temperature grain drying. In XXII International Congress of Work Study and Labour Management in Agriculture. CIOSTA/CIGR U 23–27 Hohenheim.

Ryniecki A (1985). Application of mathematical modelling and computer simulation in analysis of near-ambient wheat drying. PhD Thesis, The Agricultural University, Poznan, Poland (In Polish).

Sharp J R (1982). A review of low temperature drying simulation models. *J Agric Engng Res,* 27 169–190.

Sharp J R (1983). The design and management of low temperature grain driers in the UK — A simulation study. Natl Inst agric Engng, Silsoe, Div Note DN 1204 (unpubl).

Sharp J R (1984). The design and management of low temperature grain driers in England — a simulation study. *J agric Engng Res,* 29, 123–131.

Smith E A, Bailey P H (1983). Simulation of near-ambient grain drying. II Control strategies for drying barley in Northern Britain. *J agric Engng Res,* 28(4), 301–317.

Eleventh CIGR International Congress on Agricultural Engineering

Call for Papers

THE 11th International Congress on Agricultural Engineering will be held in Dublin, Ireland on 4–8 September 1989. The Congress will be held in historic Trinity College in downtown Dublin within walking distance of all major city attractions. Low cost accommodation is available on campus while a variety of hotels are available nearby. A full social and accompanying persons programme will be provided including pre- and post congress tours.

Professor McNulty is first Vice-president of CIGR (International Society of Agricultural Engineering) and acting as Congress Public Relations Officer.

The first announcement and call for papers has recently been mailed worldwide. A wide variety of themes have been announced including rural roads, peatlands, farm buildings design, environmental control, soil tillage, crop harvesting, agricultural processing, electronics and robotics, computerised management, ergonomics, education etc. If you wish to present a paper or poster on these or related themes forward a 200 word abstract to John Carvill, 22 Clyde Road, Dublin 4, Ireland.

For further copies of the first announcement or additional information contact Professor Paul McNulty at the Agricultural & Food Engineering Department, University College, Dublin 2, Ireland.

Farm Electric Centre — twenty-one years of service

K Weare

ON July 5, 1967, Her Majesty Queen Elizabeth the Queen Mother signed the visitors' book in a new permanent unit at the National Agricultural Centre (NAC). This was to mark the opening of what was then the Electro-Agricultural Centre, renamed in December 1971 the Farm Electric Centre. For the last 21 years this unit has been the focal point of the electricity supply industry's free advisory service to agriculture and horticulture throughout the United Kingdom, and has supported the agricultural engineers in the Electricity Boards.

From the outset, the Centre fitted well into the original concept of the National Agricultural Centre, which had been established at Stoneleigh just two years earlier. As Lord Netherthorpe, the then President of the Royal Agricultural Society of England, said in his Presidential message at the 1965 Royal Show: "The Royal Agricultural Society of England has now a unique opportunity to serve both agriculture and the nation by fostering a fresh and urgent spirit of co-operation and common endeavour amongst all those working within and serving the industry. The Society boldly accepts this stimulating challenge and looks to every sector of the industry to participate".

The electricity industry did indeed participate. There had been Agricultural Specialists in Area Boards for a number of years, but the establishment of the NAC provided the ideal geographical location for a national co-ordination centre for the electricity industry's activities in this market. The Electro-Agricultural Centre was set up to provide both commercial and technical information on all applications of electricity in agriculture, provide appropriate training, lecture, demonstration and conference facilities on a national and regional basis, and provide exhibits and features for all special events at the NAC such as the Royal Show.

The Farm Electric Centre is staffed by qualified engineers and is open throughout the year. Its exhibition hall houses a unique display of over 300 items of energy-efficient electrical equipment used in agriculture and commercial growing today. A technical library contains information on electrical equipment of more than 1500 manufacturers.

Computers are extensively used for: developing design programs to calculate, for example, heating and ventilation requirements for livestock buildings and lighting for horticulture; monitoring and analysing data for development projects; maintaining a nationwide project data collection system. This is supported by a range of more than 40 free publications covering the use of electricity in livestock production, crop conservation and horticulture, including technical handbooks and technical data sheets.

Great emphasis is placed on practical assistance to the farming and growing community. To gain this experience, the Farm Electric Centre carries out on-site development projects in conjunction with farmers, growers, manufacturers, universities and colleges. These projects range from simple testing and running-cost calculations for equipment and techniques to detailed projects. Video tapes are produced of certain development projects to allow farmers and growers to see the actual processes and techniques in operation.

The electricity industry takes this active involvement very seriously, and this year became one of the sponsors of the National Agricultural Centre's Pig Unit to help improve the cost competitiveness and systems refinement of UK pig production.

George Jackson, Agricultural Director of the Royal Society of England said at this year's Royal Show: "The Farm Electric Centre has an established track record in the application of electrotechnology to agricultural and pig production both in the UK and internationally". This is a measure of the Centre's expertise.

In addition to handling over 1000 technical enquiries each year, staff at the Centre are committed to a programme of lectures, seminar presentations and participation in national exhibitions. Because of their extensive knowledge and practical experience, staff at the Centre are involved in numerous training and educational courses. These include courses and seminars for groups of farmers, growers, advisory bodies, manufacturers and college students. Staff also lecture on a regular basis at three universities.

Today, electricity represents 24% of fuel energy used in UK agriculture and horticulture, double that of barely 15 years ago. It accounts for less than five per cent of total costs, but it can have a major impact on efficiency and profitability. The Farm Electric Centre helps in the selection and application of electrical equipment and the effective use of electricity in all aspects of agriculture and horticulture either by direct contact or through the electricity boards, with the intention of improving this essential efficiency and profitability.

The Farm Electric Centre may be contracted at the National Agriculture Centre, Stoneleigh, Kenilworth, Warwickshire CV8 2LS. Telephone 0203 696512. The Manager is Dan Mitchell.

Keith Weare is Senior Press Officer for the Electricity Council.

Books received

W C T Chamen

A WIDE range of books has been received over the last few years for which reviewers have not been found. Therefore these books are listed below generally in some sort of subject grouping together with brief synopses.

Computer Applications in Agricultural Environments

J A Clark, K Gregson, R A Saffell

Publisher: Butterworth Scientific Ltd, Westbury House, Bury St, Guildford, UK, GU2 5BH, 1986. ISBN 0 407 00429 7 £60 (Hardcover)

Proceedings of the 42nd Nottingham Easter School are reported. These are aimed to promote an awareness of the application of computer techniques, common to many disciplines, which have been developed and used in a wide variety of applications. The proceedings may be divided into a number of areas; the theoretical aspects of computer control, applications to the control of the environment of plants in greenhouses, to grain driers etc, in the environmental control for animal housing, problems in the food industry and in data logging.

Irrigation with Reclaimed Municipal Wastewater – A Guidance Manual

G S Pettygrove, T Asano

Publisher: John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex, UK, PO19 1UD, 1986. ISBN 0 873 71061 4 £32.15 (Hardcover)

For use in the planning, design and operation of agricultural and landscape irrigation systems to arid and semi-arid environments, particularly those occurring in California. With emphasis on the beneficial use of reclaimed wastewater, it differs from many other publications dealing with this subject.

Rural Groundwater Contamination

F M D'Itri, L G Wolfson

Publisher: John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex, UK, PO19 1UD, 1987. ISBN 0 873 71100 9 £37.75 (Hardcover)

The focus of this book is on groundwater contamination in the US from agricultural sources, but it also includes an overview of the sources, impacts, assessment methods and health risks of groundwater pollution. In addition, the necessary remedial actions are explained and programme strategies recommended. The book is organised into six major sections covering the above subject matter and contains papers from a large authorship.

Land Application of Sludge – Food Chain Implications

A L Page, T J Logan, J A Ryan

Publisher: John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex, UK, PO19 1UD, 1987. ISBN 0 873 71083 5 £31.70

This book was the result of a workshop which brought together 31 scientists knowledgeable in the subject of application of municipal sludge to agricultural land. The workshop aimed to critically examine current published and unpublished information on this subject and to produce in report form an assessment of the current knowledge about factors known to affect the impact of trace constituents on crops and consumers.

Environmental Impacts of Agricultural Production Activities

L W Canter

Publisher: John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex, UK, PO19 1UD, 1987. ISBN 0 873 71066 5 £46.00 (Hardcover)

The author aims to provide information useful in precluding environmental deterioration whilst allowing for the necessary expansion of agricultural production. The actual and/or relative environmental impacts resulting from existing and emerging agricultural production technologies are summarised and information useful to planners is included. The seven chapters and three appendices cover trends in, and constraints to, increases in agricultural production, new techniques, land use pressures and rising energy and water prices. Conservation and environmental improvement policies are addressed as production constraints. The effect of agricultural practices on the water and soil environment and on the air and noise environment are highlighted and reviews of case studies include some on conservation tillage and organic farming. A trade-off analysis of eleven emerging agricultural production technologies, based on their anticipated agricultural production efficiency and environmental impacts are given. The appendices include a glossary of the key agricultural terms used, an annotated bibliography and a summary of the top lines of research identified for the above trade-off analyses.

Irrigation Development Planning

J R Rydzewski (editor)

Publisher: John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex, UK, PO19 1UD, 1987. ISBN 0 471 91506 8 £25.95 (Hardcover)

The Editor has drawn on eleven authors and 23 years of experience at Southampton University to publish a book which provides engineers with an awareness of the multidisciplinary nature of irrigation development, and familiarity with advances in the technologies involved. The book responds to an increased demand for engineers engaged on planning of irrigation projects and recognises the lack of training opportunities now available in Third World countries. It deals with the assessment of water, land and human resources involved in such developments, and leads on to consideration of project formulation and appraisal, suggesting how such project proposals should be presented. Irrigation design and agricultural aspects of the problem are not included.

Handbook of Hydraulic Engineering

A Lencastre

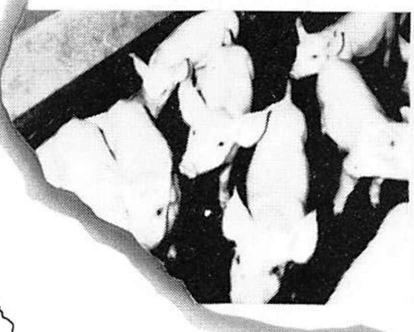
Publisher: John Wiley & Sons Ltd, Baffins Lane, Chichester, West Sussex, UK, PO19 1UD, 1987. ISBN 0 745 80095 5 £69.50 (Hardcover)

This is a revised edition of a manual first brought out in 1957 which has been translated from the original Portuguese into five languages. The English edition originates from the 1983 revision under the translation editorship of Patrick Holmes of Imperial College, London. The Handbook provides an understanding of hydraulic principles combined with the knowledge and experience of practising engineers. Chapters cover the physical properties of fluids, theoretical bases of hydraulics, hydrostatics, steady flow in pipes, open-channel flows (both uniform and steady), flows in porous media, the use of orifices and weirs in flow measurement, centrifugal pumps and the protection of pipelines with transient flow in pressure conduits. There is also a large section of tables and graphs related to the different chapters.

Tim Chamen works in the Vehicles and Cultivations Division of AFRC Engineering at Silsoe, Bedford. He is the Hon Secretary of the SE Midlands Branch of the Institution.

Many farmers take advantage of our free advice...

"Better health and 30% lower costs with electric heating"



Tony Walters, pig farmer, Gisburn

Tony Walters called in Alec Stoddart, his North Western Electricity Board (NORWEB) agricultural engineer, to help reduce the cost of heating the open forward creep areas of his 35-sow farrowing house. This resulted in the installation of insulated box creeps with controlled electric heating which gave improved piglet performance with a 30 per cent reduction in heating costs.

NORWEB also advised on the conversion of a flat-deck weaner house. Electric heating was installed following a free computer study by the Farm-electric Centre. The overall con-

Electricity Board overcomes harvest bottleneck

Keith Smart, arable farmer, Churcham, Gloucester

Keith Smart of Harold W Smart and Son Ltd began planning his new grain drying store two years ago. Throughout this period he received valuable help and advice from Barry Hopkins, Midlands Board agricultural engineer for Gloucester and Hereford.

This early link with the Board also helped with arrangements for the electricity supply.

Keith Smart's new Brackley storage drier will take in grain just as fast as his combine and grain trailers can deliver it. The drier plus store provides storage for 1,000 tonnes of cereals in addition to existing storage facilities. And is flexible enough to barn-dry his hay crop should he ever need it.

The continuous-flow drier will st

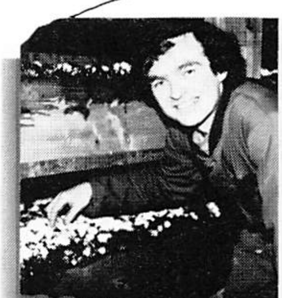
"WE'VE CUT OUR WATER HEATING COSTS FROM £1 TO 30p PER CALF"

Jane and Philip Oliver, calf rearers, Carperby, Wensleydale

Specialist calf rearers Jane and Philip Oliver called in the North Eastern Board's agricultural engineer John Goodwill to help design a more economical system for heating water to provide warm milk feed. The result was a system that more than paid for itself in the first six months.

"We've cut our water heating costs from £1 to 30p per calf," said a delighted Philip

"HEAT PUMPS INCREASE OUR MUSHROOM YIELD AND HALVE COSTS"



Priest Bros, Bonneyhale Farm, Ealand, South Humberside

When the Priest brothers installed three 12m. Monomech sheds they contacted their local Yorkshire Electricity Board agricultural engineer —Michael Brown, who recommended that heat pumps should be used for controlling the shed temperature. Performance of the new growth rooms was so impressive that the Priest brothers have gone ahead and installed heat pumps in four more sheds resulting in increased production at less than half the running costs of their previous oil-fired system.

..you could, too.

Our FARMELECTRIC agricultural engineers regularly advise farmers on cost effective methods of using electrical equipment.

Their friendly, expert help and advice is free, and supported by a wide range of free technical publications and the resources of the Farm-electric Centre at Stoneleigh.

If you too wish to profit from their expertise and would like your local Electricity Board agricultural engineer to contact you for an appointment—ring us at the NAC, Stoneleigh on Coventry (0203) 696512 quoting "FARMELECTRIC Service" or fill in and return the coupon.

To: Dan Mitchell, Farm-electric Centre, National Agricultural Centre, Kenilworth, Warwickshire CV8 2LS.

☐ Please arrange for my local Engineer to contact me.
☐ Please send me your list of free publications.

Name

Address

Telephone

Electricity Board

FARMELECTRIC

Energy for Life

The Electricity Council, England and Wales AE/12.9