A G Holland

Journal and Proceedings of the Institution of Agricultural Engineers

SUMMER and AUTUMN 1967

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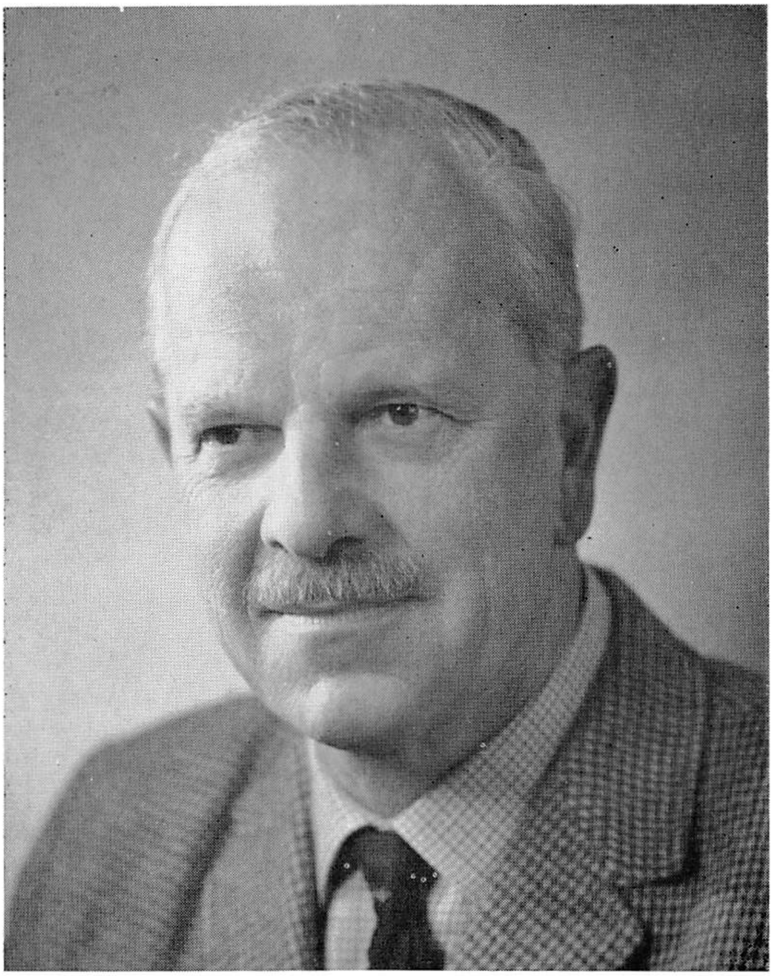
THE PRESIDENT



Mr T. SHERWEN

At the Annual General Meeting of the Institution on 11 May 1967, Mr T. Sherwen C ENG, MI MECH E, MSAE, MI AGR E, was elected President of the Institution for 1967-68.

Mr Sherwen, who first joined the Institution as a member in 1956, served on the Council from 1959 and then became Vice-President. In 1965 he was made President-Elect. He has served on a number of Institution Committees and was for two years Chairman of the Finance & General Purposes Committee. A keen Branch supporter, he served a term as Chairman of the Western Branch.

Much of Mr Sherwen's early career was concerned with automobile engineering, in which he served an apprenticeship. During the second World War he was engaged for part of the time on hydraulic gun turret development for the R.A.F. After the war, he was concerned with agricultural implement design and development at Coventry and he later became chief agricultural designer with R. A. Lister of Dursley. From 1956 to 1961, Mr Sherwen was Managing Director of Horstmann and Sherwen. Latterly, he has become a freelance consultant and this allows him, in his own words, "to dabble in anything that looks interesting". Much of his recent work has had a hydraulic basis.

JOURNAL AND PROCEEDINGS OF THE INSTITUTION OF AGRICULTURAL ENGINEERS

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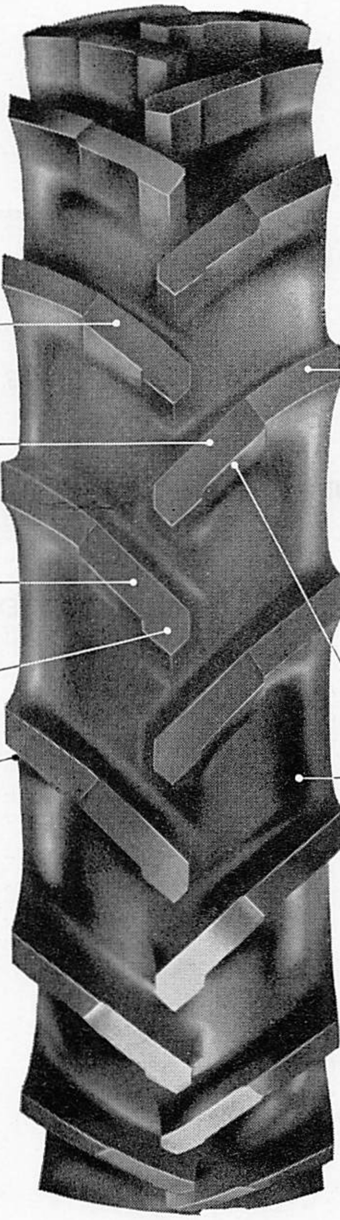

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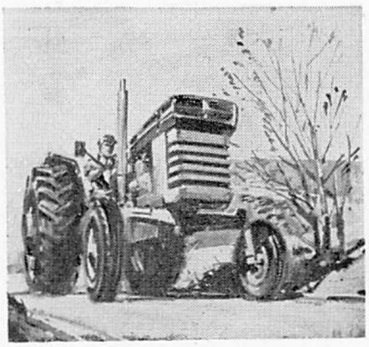

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The Institution of Agricultural Engineers

SPRING NATIONAL MEETING 1968

to be held at
The Farm School, MILTON, nr. Cambridge
Thursday 28 *March* 1968
10.15 hrs to 16.30 hrs

THE APPLICATION OF FERTILIZERS IN AGRICULTURE

An Examination of the Agronomic and Technical requirements for effective crop nutrient application.

AN ASSESSMENT OF THE AGRONOMIC REQUIREMENTS OF FERTILIZER APPLICATION
by M. Holmes, Department of Soil Science, Levington Research Station.

ACHIEVING THE DISTRIBUTION REQUIREMENT FOR SOLID FERTILIZERS
by T. L. Green, Fertiliser Marketing Department, Agricultural Division, Imperial Chemical Industries Limited.

ACHIEVING THE REQUIRED DISTRIBUTION OF LIQUID NUTRIENT SOURCES
by J. Byass, National Institute of Agricultural Engineering, Silsoe.

PROJECTING FUTURE TRENDS IN NUTRIENT SOURCES AND THE REQUIREMENTS FOR EQUIPMENT TO MEET THE NEEDS OF SUCH SOURCES
by G. W. Cooke, Head of Chemistry Department, Rothamsted Experimental Station.

Ticket Admission only

ANNUAL CONFERENCE and ANNUAL GENERAL MEETING 1968

to be held at
The Institution of Mechanical Engineers
1 Birdcage Walk, LONDON, SW1
Thursday 9 *May* 1968
Whole Day—Times to be announced

Presidential Address—by T. Sherwen, President, I AGR E

NEW USES OF PETROLEUM FRACTIONS IN AGRICULTURE

A series of three papers and discussion covering such aspects as agricultural sprays, soil conservation, and moisture conservation. (Titles and speakers to be announced).

Ticket Admission to Conference only

ANNUAL DINNER 1968

to be held at
St Ermin's Hotel, Caxton Street, LONDON, SW1
Thursday 9 *May* 1968
18.15 hrs for 18.45 hrs

PRINCIPAL SPEAKER:
The Rt Hon Anthony Wedgwood Benn, MP, *Minister of Technology*

Ticket Admission only

Further details of all the above events will be announced

INSTITUTION NOTES

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By the time this issue of the *Journal* is in print, the widely publicized Agricultural Engineering Symposium of the Institution will have taken place. Enormous interest has been aroused by this event, the first of its particular kind to be held in Britain and undoubtedly the largest and most complex activity ever organized by the Institution.

A full report of the Symposium, staged at the National College of Agricultural Engineering, Silsoe, Bedford, during the period 11-14 September, will be appearing in a subsequent issue of the *Journal*, together with details of the availability and cost of the Bound Proceedings to be published in 1968.

Publications

This issue of the *Journal* is a combined Summer and Autumn issue, owing to the rescheduling of material necessitated by the recently held AES. The Winter issue will contain the Proceedings of the Annual Conference 1967 and will reach all members during January next, together with the *Yearbook and Membership Directory 1967-68*

Annual General Meeting

The Institution held its Annual General Meeting immediately after the first session of its Annual Conference on 11 May. It took place in the Lecture Theatre of The Institution of Mechanical Engineers, London.

After the Minutes of the 1966 AGM had been approved, the retiring President (Mr J. H.W. Wilder) formally moved the adoption of the Annual Report of the Council for 1966. In so doing, he singled out for special mention the outstanding work of the Examination Board in connection with the successful innovation of the new-style National Diploma in Agricultural Engineering and Institution Part II examinations. The efforts of the Membership Committee during a difficult year were commended, as also was the valuable contribution of the Branches to the overall well-being of the Institution. The President concluded by paying tribute to the staff and thanked them for the help they had given him during his term of office.

The Hon Treasurer, Mr E. Atkinson, formally presented the Accounts of the Institution for 1966. He said it was remarkable that in the face of increasing economic pressure the Institution had just managed to break even but he believed that the time was not far distant when the main fabric of the Institution's financial structure must undergo intensive review.

Nominations to fill vacancies among Officers and Members of Council were confirmed. These included the names of Mr T. Sherwen as the incoming President; Mr H. C. G. Henniker-Wright, President-Elect; Mr J. A. C. Gibb, Vice-President; and Mr R. A. Bayetto, Dr P. C. J. Payne, Mr C. V. T. Dadd, Mr R. E. Arnold and Mr J. A. Cole-Morgan as Members of Council.

Following the closure of the AGM, Mr J. H. W. Wilder formally invested Mr T. Sherwen, the new President, with the Badge of Office and wished him a successful Presidential term. Mr Sherwen expressed his appreciation of the high honour bestowed on him and said he looked forward to doing all in his power to advance the Institution's role and function on behalf of the agricultural engineering fraternity.

Future Institutional Activities

During the Winter Session 1967-68, there will be an extensive programme of open meetings, conferences, visits and social occasions, planned and administered under the joint aegis of the Council, the Papers Committee and the nine regional Branch Committees of the Institution. By the time this issue of the *Journal* is circulated, many members will already have received preliminary details of events scheduled for the Autumn; a booklet will also have reached every member, giving details of all confirmed fixtures throughout the United Kingdom up to May 1968. Members everywhere are once again asked to do their utmost to support Institutional activities in their Branch area, not only through their own attendance but also by bringing along guests who may well prove to be suitably qualified, potential members of the Institution, in either corporate or non-corporate grades.

THE ANNUAL DINNER OF THE INSTITUTION LONDON, 11 MAY, 1967

It was with regret that members and guests at the Annual Dinner learned that illness had prevented Maj-Gen. C. Lloyd, CB, CBE, TD, B SC, F INST P, Director General, City and Guilds of London Institute, from being present as the Institution's Guest of Honour. It was gratifying, however, that his place had been taken by the Director of Further Education and Training of the Institute, Mr D. E. Wheatley, MA, B SC.

Proposing the Toast 'The Institution', Mr Wheatley first of all said he felt it was particularly appropriate that, at this important time when education and training were topics in many ways in the forefront of the interests of the Institution of Agricultural Engineers, he should have been chosen to undertake the responsibility of proposing the toast of the Institution—appropriate, in that the Institution and his own Institute had long been partners in education and training. The Institution of Agricultural Engineers and the City and Guilds in conjunction had been awarding the Certificate in Farm Machinery Operation and Care since 1953.

Just as in those days the national scale of the response to, and demand for, what had been originally a scheme for a part-time course for tractor drivers in Norfolk, arranged on a local basis by the Institution of British Agricultural Engineers, had shown the vital importance for agriculture of education and training at all levels to increase efficiency and maximise output, more than ever was education and training important today.

Mr Wheatley referred to two recent developments in education and training that affected agricultural engineering, as part of agriculture as a whole— the Report (better known as the Pilkington Report) of the Advisory Committee on Agricultural Education of the National Advisory Council for Education in Industry and Commerce (of which Advisory Committee he had been a member); and the Industrial Training Act.

To take the wider aspect first: the Industrial Training Act would have far-reaching implications for the training of manpower in all aspects of British industry, from managers at the top to operatives at the base of the structure. It would eventually have a very significant effect in still further improving standards of efficiency in doing the job, and hence in increasing productivity. The record of this Institution in these respects as in the field of education and training itself, was particularly praiseworthy. Agricultural engineering in point of numbers was not a large industry, and was further broken down into branches concerned with the manufacture, distribution, application in the field, maintenance and servicing, and repair, of agricultural equipment. Yet in recent years there had been a tremendous increase in the output of agricultural machinery, so that it now accounted for the fourth largest export of this country, while concurrently the degree of mechanization of British agriculture had advanced extremely rapidly. This expansion had taken place in the situation of a corresponding increase in the membership of this Institution.

Mr Wheatley said he knew there was at the moment some uncertainty among agricultural engineers concerned with the distribution, repair and servicing of farm machinery as to their position under the Industrial Training Act, and that the training recommendations of the Engineering Industry Training Board (within which the manufacturing aspect of agricultural engineering is included) were not entirely appropriate to the requirements of, for example, the service mechanic for whom the City and Guilds 260 and 261 schemes had been designed. These aspects had now been specifically excluded from the scope of the Engineering Industry Training Board. Mr Wheatley said it was his hope that, whether they were eventually included in the responsibilities of the Agricultural Industry Training Board or of that for Road Transport, the value of the Institution and the Institute having worked together in producing the City and Guilds schemes of education and training, related as they were to the experience of the apprentice 'on the job', would continue to be recognized.

Turning to the changes in the educational pattern recommended by the Pilkington Report, Mr Wheatley drew attention to the consultations taking place as to the way in which new qualifications, based on a new system of courses and therefore of examinations, could best be provided. The Pilkington Committee had recommended the provision in each of the main branches of agriculture —of which agricultural engineering forms one—of Higher and Ordinary National Diplomas similar to the provision that exists for other industries. It had been the Committee's hope that the Secretary of State for Education and Science would establish a Council for Agricultural Examinations, to co-ordinate policy for the various branches and to provide liaison between award-giving examination boards which would operate within terms of reference to be prescribed by the Council. These award-giving boards, it had been envisaged, would be substantially those at present in operation, and in the case of agricultural engineering the Board would be the present Examination Board in Agricultural Engineering, to whose work Mr Wheatley said he wished to pay tribute.

Mr Wheatley said The Institution of Agricultural Engineers was indeed to be complimented because it had always recognized the essential importance of providing a 'ladder of opportunity' for the most able man to reach the top. These opportunities had been provided both in the membership structure of the Institution and in the recognition given where qualifications were concerned. In this connection, Mr Wheatley referred especially to the opportunity that existed for the apprentice who had successfully completed the City and Guilds examinations for Agricultural Mechanics and Agricultural Engineering Technicians to proceed to a course at Writtle or the West of Scotland Agricultural College leading to the National Diploma in Agricultural Engineering and thence to managerial, advisory, teaching and research appointments. He said he very much hoped that these oportunities would continue: it seemed to him vital that they should. The Institution had rightly recognised the importance for the industry of drawing from both agriculture and engineering and from those who had come from the workshop floor equally with those who came from the university.

Both the Industrial Training Act and the implementation of the Pilkington Report would present tremendous opportunities but there was a need to ensure that the increasing formalization of educational and training patterns did not over-emphasize the stratification of industry into different levels of employment—operatives, craftsmen, technicians, technologists and managers—with quite distinct training needs and recommended training programmes, rather than provide increased opportunities for upward progression.

In something of a similar way, the introduction of Higher and Ordinary National Diploma awards might tend to over-emphasize the desirability of formal 'Academic' qualifications—'O' and 'A' levels—for entry to courses, and this too might prejudice the chances of the 'late developer', but so long as one could be sure that Institutions like I AGR E, firmly based on industrial requirements and experience, had a part to play in these arrangements, one could rest assured that hazards of this kind would be avoided. Whatever the outcome of the present consultations as to examinations and their administrative machinery, it was to be hoped that the principle of progression and of interchangeability which the Pilkington Committee had been at pains to insist upon, would be retained.

Mr Wheatley said he had tried to indicate those points of development in education and training which seemed to him to be of special importance at this time. He knew of the close interest the Institution of Agricultural Engineers had always taken in Education and Training, and that this interest had created an attitude towards the education and training of those engaged in agricultural engineering that was quite outstanding. He was therefore confident that the challenges for the future that would arise from the developments he had indicated would be met by the Institution in the same spirit that it had always shown. Mr Wheatley concluded with the hope that the Institution would continue to progress from strength to strength.

The response was made by Mr T. Sherwen, C ENG, MI MECH E, MSAE, MI AGR E, President of the Institution. He said he hoped Mr Wheatley would forgive him if he began on a note of regret. The regret was not at all that Mr Wheatley was present, but that Maj.-Gen. Lloyd was not. Maj-Gen. Lloyd with his well-known affection for agricultural engineering, had been looking forward keenly to being here. It was a great sorrow that ill-health should have prevented the Institution from doing him the honour he deserved.

In seeking the company of Gen. Lloyd tonight, there had been a twofold intention. First, the Institution had wanted to pay tribute to the man himself—one whose contribution to the advancement of craft and technician education in Britain was clearly on record for all to see in the calibre of the leadership of his organization. Secondly, there had been the desire to show some outward sign of appreciation of the City and Guilds of London Institute itself, especially in the field of agricultural engineering education and training. The Institution had been fortunate to secure in Gen. Lloyd's stead, no less a person than Mr Wheatley, who, in the circumstances, had stepped into the breach.

Mr Sherwen said he thought Mr Wheatley was to be congratulated on having put together a speech of remarkable interest and clarity, considering that three days ago, he had had no idea he was going to give it. It was just as well that he had the gift of lucidity, because any utterances from City and Guilds on the subject of agricultural engineering education were going to be listened to with a certain attention in the coming months. A great difficulty in any discussion of this subject was the incessant need to stop and talk about the meaning of words. For example, when the Department of Education and Science talked about 'technician-level' education for engineers one found that they were referring to a level ranging between Ordinary and Higher National Diploma; and this of course was echoed by the Council of Engineering Institutions who were being encouraged to adopt the expression 'Professional Engineer' and 'Technician Engineer' to define one from the other, the former being to the standard of a University first degree in CEI terms.

Engineers today stood on the threshold of an era, in which they were called upon to define the meaning of words very precisely and, more important, to reach agreement about those meanings with the people in education, in training, in career guidance and in industry with whom they were dealing. It was a matter of semantics and it was a problem to be overcome as early as possible in any negotiations between one body and another where the establishment of levels of engineering attainment in an academic sense, were at issue.

Mr Sherwen said he must speak of redefinition as well as definition. By redefinition he meant something quite different, more like transfiguration, such as one had been witnessing in the great chartered engineering institutions of this country. One must not underestimate the extent either of what they had achieved, or of what they hoped for. Their achievement had been to gear fourteen major engineering disciplines to a common purpose through the formation of CEI and thus to exert a unity of outlook in spreading a mantle of consistency over the vast spectrum of British engineering such as could never have been foreshadowed in the younger days of many of those present. This Institution, although not within CEI, had no quarrel with it and applauded the principle of conferring professional status upon suitably qualified engineers. It would be idle to pretend, that the spreading

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THE APPLICATION OF AGRICULTURAL ENGINEERING IN DEVELOPING COUNTRIES

by

A. H. BUNTING, MSC, D PHIL*

Presented at the Spring National Open Meeting of the Institution on 16 *March* 1967 *at the University of Reading*

OBJECTIVES AND DEFINITIONS

My objectives in this paper are simple. I want to review the contribution which engineering can make to the life and work of farming people in developing countries, and I want to suggest that this contribution must often be very different from that which it makes to the agriculture of advanced countries.

Developing Countries

I take 'developing countries' to be those in which the great majority, often over four-fifths, of the population live on the land and depend directly on agriculture for their livelihood, in which farm incomes and gross national product are low, and in which agriculture is still largely of a traditional and static type, depending largely on human and animal power, while industry is but little developed. This was the condition of all countries before the middle of the seventeenth century, when agriculture began to change in North-Western Europe. This change has spread through much of Europe and North America, side by side with the development of industry and large markets for agricultural produce. Today, though some countries or parts of countries in Europe are still 'developing', most of the developing countries are in the tropics and subtropics, and their relative position is becoming steadily poorer, because of the exponential nature of industrial and agricultural change in the advanced countries.

The tropics are by no means a homogeneous region: they are extremely diverse in geographical and social conditions. They range from the countries of the low-lying equatorial forest regions, where it is always hot and wet, to those of the seasonally arid, warm or hot regions on either side of the subtropical desert belts; and they include extensive areas at high altitude, particularly in Africa and America, where the rainfall is usually seasonal and temperatures relatively low. They include regions which are densely populated, like many tropical islands and parts of Kenya, as well as vast empty areas, particularly in the seasonally arid zone adjacent to the desert margins. Their agricultural systems range, often within a single country, from European-type mixed farming to extensive range grazing by nomad pastoralists, though most farmers produce food crops for subsistence, and sometimes food or industrial crops for sale. Many of them however are on the fringes only of a money and market economy, and have little or no means of acquiring or using capital. Nor do they have the knowledge or the technical ability to use new methods. Hence, even where advanced methods of production are already known, as a result of research, farmers' yields are usually very low. In these countries food supplies per head are small, while the population is usually increasing at 2 or even 3% per annum. Every combination of these diverse conditions offers different problems and opportunities for the agricultural engineer.

Agricultural engineering

Next I must define what I believe to be the scope of agricultural engineering. For me it comprehends all the applications of the engineering arts and sciences—civil, mechanical, electrical and chemical, to the production, storage and handling of agricultural products and to those aspects of rural life which closely influence these agricultural processes. The mechanization of farm operations, which is the central topic of agricultural engineering in Britain, is but one among many facets of the subject in developing countries.

Development

It is worth spending a moment to consider what we mean by development. By this term I mean an increase not only in total production but in net income per head of population, so that capital can be generated and living standards improved simultaneously. These words are easy to write, but the reality has proved extremely difficult to achieve. The important point lies in the words net income—the increased output must be worth more than the cost of producing it, and this is not always easy to attain in a developing country, even though technical means for increasing yields may be well known or not difficult to find.

That yields much higher than those currently harvested can be attained in developing countries is no longer to be doubted. The highest recorded agricultural yields of dry matter per acre have been obtained with sugar cane in Hawaii. Expatriate settlers able to use modern methods have shown in many countries that the environment, properly managed, can be made to yield far more than peasant farmers can wring from it. Experiment stations everywhere are breaking records of yield year after year. For many crops and in many areas we already know technically how to increase yields several-fold. The reasons why this knowledge is not applied in farming practice are many, complicated and often poorly understood. I shall return to them later.

* Professor of Agricultural Botany and Dean of the Faculty of Agriculture, University of Reading.

TECHNICAL PROBLEMS IN TROPICAL AGRICULTURE

In the rest of this paper I am going to forget the undeveloped parts of the temperate regions of the earth, and speak unashamedly of the tropics and tropical agriculture. I want now to review the main technical problems and consider how the engineer can help to solve them. In this section I am dealing with technical possibilities, not with whether they will pay or not.

Land, water and other natural resources: agricultural civil engineering

First priority must go to the conservation and management of the natural resources on which farming depends —principally land and water. So long as men are few and land freely available, extensive systems of shifting cultivation, of which the open fields system was one, are sufficiently stable to maintain average yields and so to provide a livelihood of a sort for farmers and their families, though often at vast costs in labour for clearing. As populations increase, shifting cultivation becomes stabilized, and unless new land can be found or some system of managed fallowing or manuring is evolved (as in Ethiopia or in the area round the city of Kano), yields tend to fall drastically except on the most fertile alluvial flood plain soils. Soil and water must be conserved and used in a planned fashion.

The clearing of new land, the protection of the soil against erosion, the removal of excess water, whether by controlled run-off or by subsoil drainage, the construction of small dams, and of irrigation channels, and the management of soils so that water can percolate rapidly into them, require very large amounts of labour if they are to be done by hand with simple tools, which is often physically impossible. Even though hand labour may be the cheapest way of doing a job, as in the clearing by farmers of areas of light woodland or scrub, a good economic case can sometimes be made, on grounds of speed and efficiency, for using tractors, and powerful ones at that, for these major tasks of agricultural landscaping. This is particularly true in the semi-arid areas, where populations are often small, and in wetter regions, where the time available to do the job may be short. In densely populated regions there may be an unanswerable case for using what are politely called 'labour-intensive' methods, even for major civil engineering works of this sort. These contrasts illustrate what I believe to be the most important generalization I have learnt from the tropics—that the best way to do a job depends so closely on the ecological and human circumstances that few generalizations about how to do things in the tropics can have any validity.

Other important civil engineering tasks on farms and in the countryside include the building of earth roads, causeways, surface-runoff catchments and storage tanks, and farm structures.

Mechanization of crop production

Considerable areas of the seasonally arid tropics, particularly the vast clay plains in the old internal drainage region of the Sudan zone of Africa from the Senegal, Volta and Niger to the Blue Nile and the Gash, are very well suited to the large-scale mechanized production of annual crops, and hundreds of thousands, if not millions of acres, formerly uninhabited, are so used.

In the temperate regions where our systems of mechanized farming were developed, water accumulates in the profile in the cold winter season, and during the crop season evaporation exceeds rainfall. Crops are sown on falling relative humidities and rising temperatures after a wet or snowy winter, and harvested as temperatures fall and relative humidity rises. The agricultural climate of the semi-arid tropics is the mirror image of this: the off-season is hot and rainless, and the soil profile becomes dry throughout. Sowing occurs when temperatures are falling and humidity rising, crops grow in the period when rainfall is greater than evaporation and are harvested in warm or hot and dry weather. This contrast greatly affects the engineering task.

Thus at Tozi in the Sudan rainlands there was no winter mat of weeds to bury, and primary cultivations, on the cracking clay plains, were needed only to prepare a seed-bed. Consequently we could use a wide-level disc plough, penetrating no more than a couple of inches, at four to five acres an hour. The sowing of sorghum, using a 14 foot drill, was very nearly as rapid. Cotton, sesame, groundnuts and maize were all speedily sown. The speed of these operations broke the labour peak which would have limited the amount of land a hand cultivator could have sown in the time, and enabled cropping timetables to be adjusted closely to the length of the available season. Weeding, which would have aggravated the labour peak, was done mainly by inter-row cultivations of various sorts, including steerage hoeing, though skill and experience were needed to carry them out, as the season advanced and conditions became steadily wetter. Insecticides and other plant protection chemicals were applied mechanically in conditions of continuously high humidity. Harvesting, at the end of the season, was done mechanically for all the crops except sesame and cotton, though the mechanical picking of the latter has recently been demonstrated in the rainlands. In combining sorghum the risks of fire and cracking grain replaced the risks of spoilage by wet which are more common in temperate regions. In shelling groundnuts we had to add water to the produce rather than dry it. Since we were not pressed for time at this stage, we could save prime movers by using a tow-behind combine and by hauling crops from the field (on dry roads) with tractors and trailers. The times of operation for several crops in 1954 are recorded in Table 1, and the figures for ancillary hand labour are in Table 2. Except for groundnuts, the machinery requirements were small.

It is in conditions ecologically similar to these, though distinctly drier, that the very remarkable average output of 1800 working hours per tractor per year have been obtained in the Sudan Gezira.

In much of the tropics, however, the conditions are far less idyllic. Where populations are dense, as in India and South China, the tractor cannot so readily be deployed, because it puts men out of work and requires fields larger than those which most farmers control. Reform of land tenure can deal to some extent with the latter question, as

Kenya's experience shows, but it is often necessary to restrict the use of tractors (except perhaps for communally or cooperatively organized primary cultivations) and use as much human labour as possible.

In wetter regions, the most important crops other than rice are perennials and the soil is wet too frequently to be worked with machinery in the conventional way. Here the visitor from a temperate region may see quite bizarre equipment—vast harvesters cutting and transporting 150 tons of sugar cane to the acre; long conveyor belts bringing pineapples, cut by walking or riding field workers, across the rows into a central transporter; glorified mowing machines to harvest tea, and so on. But often, in the wetter tropics, labour is plentiful and must be used. This gives tea, coffee, pyrethrum, tobacco, rubber and other 'labour-intensive crops' particular importance in densely populated regions. In such areas it is pointless to suggest that the 'surplus population' must be got off the land into industrial work in towns so that the land can be replanned for mechanized farming. Too often, whether on the ancient pre-Cambrian plateaux or the Quaternary alluvial plains, there are neither minerals nor power sources for industry, and no effective market for its products. One has to start with what is to hand, and if

TABLE 1

Mechanized operations in the production of various field crops, Tozi, 1954

(1 feddan—1 acre approximately)

Operation	*Equipment*	*Feddans*	*Machine hours*	*Hours/ feddan*
I. Cotton:				
Discing	MH 26 wide level disc	112.2	27.0	0.24
Harrowing	Chain harrow	74.9	13.2	0.18
Planting	MH 433 planter	98.7	40.5	0.41
Transport	Commer truck	98.7	73.0	0.74
Total and mean	Tractor	98.7	80.7	0.82
II. Groundnuts:				
Discing	MH 26 wide level disc	91.8	35.1	0.38
Harrowing	Chain harrow	27.5	4.5	0.16
Weeder mulcher	Ferguson weeder mulcher	7.9	2.0	0.25
Planting	MH 433 planter	56.1	36.0	0.64
Spraying	Ransome Cropmaster	43.5	21.3	0.49
Inter-row cultivation	Ferguson steerage hoe	62.6	34.0	0.54
Ridging	MH 768 toolbar	56.1	31.1	0.55
Lifting	Horiz. blade digger	56.1	38.1	0.68
Windrowing	MH side delivery rake	56.1	23.3	0.42
Carting and stacking	Whitlock trailer	56.1	125.0	2.23
Threshing	Ransome major	56.1	146.3	2.61
Transport	Commer truck	56.1	78.3	1.40
Total and mean	Tractor	56.1	496.7	8.85
III. Sorghum:				
Discing	MH 26 wide level	131.4	33.8	0.26
Harrowing	Chain harrow	38.1	6.8	0.18
Weeder mulcher	Ferguson weeder mulcher	7.4	1.1	0.15
Drilling	MH 306 drill	64.5	15.2	0.24
Inter-row cultivation	MH 768 toolbar	23.5	9.1	0.29
Harvest	MH 726 combine	21.4	23.0	1.08
	AC 60 combine (towed)	43.1	39.0	0.90
Threshing gleanings	Stationary AC 60 combine	64.5	8.3	0.13
Transport	Commer truck	64.5	14.3	0.22
Total and mean	Tractor	64.5	66.0	1.08
	MH combine	21.4	23.0	1.08
	AC combine	43.1	39.0	0.90
	AC combine for gleanings	64.5	8.3	0.13
IV. Sesame:				
Discing	MH 26 wide level	12.2	2.5	0.21
Harrowing	Chain harrow	25.6	3.7	0.14
Weeder mulcher	Ferguson weeder mulcher	15.0	2.5	0.17
Drilling	Ferguson seed drill	26.4	14.2	0.54
Transport	Commer truck	26.4	1.0	0.04
Total and mean	Tractor	26.4	22.9	0.87
V. Safflower:				
Discing	MH 26 wide level	155.8	59.9	0.38
Harrowing	Chain harrow	12.6	3.3	0.26
Weeder mulcher	Ferguson weeder mulcher	30.4	6.3	0.21
Drilling	MH 306 drill	68.2	22.5	0.33
Harvest	MH 726 combine	68.2	50.0	0.73
Transport	Commer truck	68.2	14.0	0.21
Total and mean	Tractor	68.2	92.0	1.35

TABLE 2

Hand operations in the production of various field crops, Tozi, 1954
(1 feddan—1 acre approximately)

Operation	*Feddans*	*Man-hours*	*Man-hours feddan*
I. Cotton:			
Handweeding	98.7	2000	20
Picking	98.7	12008	120
Transport	98.7	292	3
Total and mean	98.7	14300	143
II. Groundnuts:			
Handweeding	56.1	825	15
Windrowing	49.5	242	5
Carting and stacking	56.1	1072	19
Threshing	56.1	878	16
Gleaning	56.1	2430	43
Transport	56.1	156	3
Total and mean	56.1	5603	100
III. Sorghum:			
Handweeding	106.4	418	4
Gleaning	64.5	716	11
Threshing gleanings	64.5	17	
Transport	64.5	194	3
Total and mean	64.5	1345	21
IV. Sesame:			
Handweeding	26.4	245	9
Harvesting	26.4	661	25
Threshing	26.4	190	7
Transport	26.4	4	
Total and mean	26.4	1100	42
V. Safflower:			
Handweeding	68.2	1269	19
Transport	68.2	56	1
Total and mean	68.2	1325	20

people are the commonest means of production, available without direct capital cost, ways must be found of employing them and maximising their contribution to the economy.

Hence the engineer must look at the possibilities of using human prime movers more effectively. While peak load operations, such as primary cultivations, are almost always best done, if the fields are large enough, by conventional tractors, much of the rest of the year's work requires skill and precision rather than horse-power. I have always been impressed by the complacency with which an engineer will watch a 50 hp tractor doing delicate surface cultivations at low speed, to kill small weeds. I have no doubt that hand seeders, weeders and spraying equipment all have a continuing place in the farming of densely populated regions.

Of course, where for one reason or another labour rates are inflated, the whole business becomes distorted and the only result can be uneconomic mechanization on the one hand and unemployment on the other.

Mechanization in animal production

In intensive animal husbandry, I wonder always whether the milking machines that are displayed with such pride at official stations in many tropical areas are really the correct substitute, in undeveloped and over-populated countries, for hand milking and education in proper methods of hygiene. In other intensive animal enterprises, feed mixing may well be of great importance, particularly in the new poultry industries one sees in so many tropical areas. In extensive animal production, the engineer has much to do in connection with water supplies.

Transport and storage

In some developing countries, the wheel is still a very recent innovation in agriculture, and most transport is on the backs of men, women or animals. Simple and reliable vehicles for local transport by farmers seem to me to be a prime necessity. Where tractors can be used, the distribution of labour peaks is often such that at harvest time there is spare tractor capacity available, so that in these areas tractors and trailers, rather than motor vehicles, may be the best way of transporting crops from field to store, market or railhead. Motor vehicles may be needed at sowing time, when the tractors are working as hard as possible. Their number should be determined by the tonnage of seed and fertilizer to be transported at this time, and not by the much larger tonnage of crop to be moved at harvest.

Storage losses are said to account for anything from 10 to 25% of the harvested crop in tropical regions. The design and construction of storage facilities on the farm are very important engineering tasks. I am not thinking here of storage off the farm (for instance of groundnuts at Kano) where much larger-scale problems, of shelter, handling and control of spoilage, have to be solved and conventional methods can often be used or adapted to the local conditions.

Management

At the risk of stating the obvious, some contemporary illusions about the size of mechanized farms, where they are technically, economically and socially desirable, must be considered. In the seasonally arid parts of the earth, there are scores or even hundreds of millions of acres of land with no permanent settlements for lack of perennial water supplies. These vast stretches are often traversed seasonally by nomad cattle-keeping tribes, as in Masailand, the central Sudan or parts of central Asia, but elsewhere even this marginal form of exploitation is ruled out by tsetse flies and human and animal trypanosomiasis, and the land is permanently uninhabited. Not unnaturally many people, including ex-Premier Krushchev and the founding fathers of the East African Groundnuts Scheme, have filled these regions with visions of large mechanized farms producing crops for export to distant markets. Almost without exception, these visions have collapsed when they have been exposed to the hard facts of life. The economist, politician and engineer must always be reminded that agriculture differs entirely from manufacturing industry. In the latter, the raw materials, the processess, and the environment in which production occurs, are standardized. The only unpredictable variable is the human worker, and he can be trained or pressed into conformity, and steadily replaced by automation. He is also readily replaceable by any other worker of comparable skill. In these conditions, there are few human limitations to the size of the enterprise which, given experience and good administration, a single human brain can control.

In agriculture the conditions are quite otherwise. The main 'raw materials' of agriculture—soil and weather—vary over wide ranges in space, time or both; and weather (and hence soil conditions) varies unpredictably. No two fields, and no two farms, are alike. Fertilizer, and even seed, may be standardized, but weather and soil conditions affect the way in which they can be used. Pests, diseases and weeds add to the uncertainties with which the farmer has to deal. Hence, though the strategy of a farm can be planned, the tactics depend completely for their success on the skill, initiative and judgement of the farmer, who is spurred to exercise these qualities most fully when he has an important personal (and this almost always means financial) interest in the outcome.

Three things follow from this. First, at the level of production, the *management unit* (the farm) must never become so large that one man is no longer able to comprehend and control it, day by day, and even hour by hour, and so to make the best compromises he can with the continuously varying conditions of production. Second, the farm workers acquire a special value from their intimate experience of the variation and the special conditions of the farm, and cannot easily be replaced. Thirdly, even though the farm may work within a commercial, co-operative or socialized economy, which influences the strategic decisions, individual and private incentives are almost always necessary to make the system work at the tactical level. There are exceptions to these generalizations, for example in the Kibbutzim of Israel, and in some producer co-operatives, but *they are in fact broadly true and represent what actually happens*, no matter what one believes ought to happen or could happen.

The optimum size of a farm depends therefore on the complexity both of the environment (terrain, soils and weather) and of the agricultural tasks to be performed, and on the competence of the manager. In the Sudan rainlands, where soils are uniform and terrain almost flat, it is probably from 1000 to 3000 acres in a fully mechanized system. In an intensive horticultural system, at the other extreme, it may be as little as 2 acres. These considerations, rather than the ambitions of sales directors, also influence the number and size of the tractors and other implements required to work it. We who have actually done this sort of job are nowadays resistant to the arguments which purport to demonstrate that the current production model of a British or American tractor, quite unmodified, is the best possible tool for the job in Bongoland. We may have to use it, because we can get no other, but what we want is not sales talk but objective assessments of the type, number and mix of tractors and implements which a specified enterprise requires. This is a matter for technical and economic research, and to this matter I return below.

There are also many illusions about the size of the *production unit*, the field. The administrator often has dreams of the boundless field, worked by a fleet of crawler tractors. With hindsight, I am prepared to state as a principle that the most suitable field size, in a semi-arid region where the sowing period is short, is that on which any required mechanical operation can be completed between one heavy shower and the next. In the Sudan plains on heavy clay soils, I started with fields of about 200 acres. I ended with unfenced fields of about 15 acres, which gave me great flexibility and simplicity in management and operation. (On about 1250 acres, divided in this way, which included 250 acres of machine-hungry experiments, I used five 40 hp and two 15 hp tractors, plus one tow-behind and one self-propelled combine. On any strict economic basis, we had too many prime movers: I doubt whether we got more than an average of 400 hours a year out of any of them, because the season was so short. This adds a further dimension to the intricate problem of number and mix of tractors, to which I have already referred).

The large *vs* small tractor argument incidentally would look very different if more components and spares could be standardized between tractors of different sizes.

Ancillary activities

In areas where for one reason or another it is not possible to mechanize fully, crop and animal production are restricted by the large amount of time the people, and particularly the women, have to spend keeping themselves alive. Often, the engineer can give considerable help by mechanizing ancillary activities, such as pumping and filtering water, cutting grass, sawing wood or grinding grain. In such communities a small tractor with a range of attachments, perhaps owned by a local council or by a merchant, can release quite inordinate amounts of human labour for productive rather than maintenance tasks.

ECONOMIC AND SOCIAL ASPECTS

So far, I have dealt almost exclusively with technical problems—what could be done with machinery and how. When development consists of establishing new systems of farming, this approach is serviceable, though it may be expensive. But in fact, in most developing countries, and particularly in densely populated ones, it is inadequate. In these regions agricultural development means developing existing agriculture, and this usually means changing the whole life of the community, and not merely the techniques of production. We cannot sweep away the existing communities and start on an agricultural *tabula rasa;* we must work with what we have to hand. The engineer has therefore to be aware of the nature of social development and of the conductances and resistances to change. He is therefore brought up against the economic, social, psychological and educational background of the present agricultural systems.

Traditional agriculture is traditional and static for a very large number of reasons. Often the most elementary pre-requisite for change, a fair market where produce can be sold and consumer goods bought, is lacking. The traditional methods of agriculture usually represent the safest way in which, given the inputs at his command, the farmer can be sure, more or less, of providing food and other material needs for himself and his dependants. He dare not change the system, even by adding what looks like a profitable cash crop, for fear it will collapse. For example, he will not sow cotton early if this means that his staple cereal must be sown late. He may refuse to diversify his system by adding leys and cattle to it because the land and energy he would have to devote to them could be spent better in other directions, and he cannot see how to keep the beasts alive through the dry season anyway. Often the sacred cows would be in direct competition for food with the farmer himself. His holding is often fragmented, and he may have to pay crippling rents or interest on loans of liquid capital. His yields are usually too low, even if there is a good market, to allow him enough profit in cash to buy fertilizer, insecticides or better seed as well as clothes for his wife or schooling for his children. He certainly cannot accumulate capital to buy machinery, particularly as he already has to maintain and replace other capital items like his house. In his community there may well be landless labourers to whom he is bound by ties of kinship and whose labour, rewarded in kind, is cheaper than that of an ox or a tractor. He and his family and friends probably suffer from malaria, hookworm and bilharzia, they are usually short of protein, and they experience near-famine every year, as they wait for the new crops, particularly if last year's harvest was poor and the rains were late. At sowing-time when the peak labour load of the year is upon him, he may be so hungry that he has consumed part of his seed stock. The system of land tenure, and the fragmentation of land, may both offer obstacles to progress. Perhaps most important of all, the farmer is illiterate and untrained.

We cannot hope to transform the farming methods of such a farmer without making considerable changes in his way of life. We often know the contents of the combined social and technical package he needs, including education in farming methods, good health, timely cultivations, fertilizer, better varieties, thorough weeding, fungicides and insecticides, improved storage, a famine reserve, and a good market for his products—but we can seldom give them to him all together or even in the right order.

There seem to be two essential starting points—the right crop or crops, which the farmer can fit into his system, is technically able to grow, and can sell in a reasonably stable market at an attractive price, and a system of farmer training, to teach him appropriate methods which have been developed and tested *in his situation* by research. Given these things, as the current agricultural history of Kenya and the recent history of Mexico show, progress can be rapid. In the past 20 years this method has produced far more economic and social progress in the developing world than the headlong rush to large-scale state-directed mechanization which has been so fashionable. I am the last to say that large-scale mechanization is technically impossible; it could even be economically successful, given the right sequence of survey, research, pilot scale operations, economic assessment, logistic planning, and training. Nevertheless, *it has not succeeded in fact* in any instance known to me. Africa is littered with cemeteries in which tractors, dreams and ambitions have rotted away together in the tall grass.

RESEARCH AND EDUCATION

Perhaps the most urgent research need is for an engineering assessment of the tasks involved in changing for the better the life and work of traditional farming communities in developing countries. Such an assessment will, I think, show a need for patterns of equipment and services very different from the established outputs of the farm mechanization industry in advanced countries. This nettle has been grasped already in France and in South Africa, and possibly in other countries also: we in Britain have tended to lag behind.

Among the most important general problems are the choice of prime movers and means of transport in different technical, economic and social situations; rural energy sources in energy-starved countries, now and in the future; the design of implements for use with human or animal prime movers; systems of cultivation (perhaps incorporating herbicides) which use power economically, for example by restricting major cultivations to periods when the soil is not dry or compacted; problems associated with storage and with the water content of materials (including chemicals as well as seed or produce); and efficient methods of handling perennial and root crops.

A special word is needed here on ox-ploughing. How oxen are in fact fed and watered properly (rather than allowed to scavenge) and got into first class working condition at the end of the dry season to face the peak load, particularly in areas where animal health is poor, I do not know. Questions about the economics of ox-ploughing are usually parried by statements about the difficulty of operating and maintaining tractors and ploughs, and the virtues of farmyard manure. Poor maintenance and management of animals cannot be the right counter to poor maintenance and management of tractors and implements. Maybe I do not fully understand these matters, but it seems to me that an objective technical/economic study of the question is long overdue.

Engineering research on these matters must plainly be part of research on farm systems in general so that the engineer's contributions are associated with those of the agronomist, the breeder, the soil scientist, and the economist. The engineer must do his best to see the process, and his characteristic contribution to it, as a whole. He will be particularly effective, along with the economist, in operational studies and pilot-scale trials.

Finally the engineer has a vitally important part to play in the process of education, without which technical and social change cannot occur. It distresses me, thinking back on my service in research in tropical agriculture, to realize how little attention I paid to the problem of producing change in agriculture—to considering in what circumstances change can occur; what helps and what hinders change; how my own research results could be put into forms which the farmers could use; how they could be communicated to the farmer; and how the farmer could be helped to apply them. We must find ways to end the present situation, in which the ring fence round the experimental station so often divides high yields, produced by the simultaneous application of many improved practices, mostly involving engineering, from farming methods and systems which are still in the Iron Age, if not in the Neolithic. Education is one of the most important of these ways. Hitherto we have tended, of necessity, in developing countries, to concentrate on producing graduates for posts as administrators, senior executives and scientists. It is now time for us to tackle the education of the farmer himself, poor and illiterate as he is, and of his immediate instructors at the lower levels of the extension service. We must obtain and give them the right sort of information in a planned and effective way. It is through this process alone that the contribution of the engineer and his colleagues can attain its greatest effect in increasing the health, wealth and happiness of mankind.

Annual Dinner of the Institution (continued from page 44)

of this universal mantle would not at the same time create problems for a specialist Institution like I AGR E, an industry-based organization which had thrived on the mandate that it had in its midst the professional engineer and the technician engineer. The Institution had a duty no less to one than to the other. Mr Sherwen said that if there was to be redefinition the Institution should redefine itself with a view to the industry in which it was rooted, having regard to the present and future needs of that industry's technical manpower deployment at the various levels where that need existed. Any industry-based Institution which wandered very far from that concept was likely to find itself becoming a distinguished white elephant.

Mr Sherwen said that the Institution must fairly soon find a way of giving outward recognition to those of its corporate membership who could claim to be termed 'professional engineers'. He said he was not prepared to suggest at this moment how this should be done but it was being actively studied. If and when a way was found, it must be in such a way that the other categories of membership did not suffer diminution of status.

There were a great many students in the Institution at present whose avenue to Graduate and corporate membership lay via the City and Guilds of London Institute 260 and 261 Certificates and thence via the ND AGR E or Part II examination to qualify as Graduates. Mr Sherwen said he would not conceal his concern at the fact that with the trend towards establishing the professional engineer at degree level and the technician engineer at National Diploma level, there was every possibility that the City and Guilds Technician, even with the elevation of the syllabus that had resulted in better trained boys than ever before emerging at this level, was likely to find himself having to repudiate the term 'Technician' conferred upon him by City and Guilds and accept the term 'Craftsman' conferred upon him by the Department and CEI. It would be wrong to conceal the fact that the Department of Education which, only a few short years ago had been instrumental in persuading this Institution to offer the 261 Holders an avenue of advancement, was now finding this fact an uncomfortable one to live with.

The Toast to 'The Guests' was proposed by Mr H. C. G. Henniker-Wright, MI AGR E, President-Elect of the Institution and the reply was given by Mr J. G. Jenkins, Immediate Past Chairman of the Oxford Farming Conference and Past President of the Scottish N.F.U.

SYSTEMS OF MECHANIZATION FOR AGRICULTURE IN DEVELOPING SEMI-ARID COUNTRIES

by J. C. HAWKINS, B SC, NDA, MI AGR E*

Presented at the Spring National Open Meeting of the Institution on 16 *March* 1967 *at the University of Reading*

I. INTRODUCTION

The introduction of machinery into the agriculture of developing countries can on its own produce limited progress. As a general rule, mechanization rarely leads to higher yields per acre unless improved agricultural practices are adopted at the same time. More often mechanization brings higher returns as a result of economies in labour or increases in the area that can be cultivated with a given labour force. Thus, unless the area cropped or the number of crops per year can be increased, the introduction of machinery on to a family holding, where most of the agricultural operations are being done by hand, very often employs extra capital only to make life easier for the family without increasing its income.

It follows, therefore that successful mechanization in developing countries with their high proportion of small farms can usually be achieved only when accompanied by changes in agronomy, land ownership or tenure or by the creation of some way of making machinery available to small farmers without the need for each one to buy his own. This paper is written on the assumption that such changes will eventually take place and so the present skill and financial status of farmers in developing countries has not necessarily been taken as the controlling factor deciding the type of equipment required. Further, it is assumed that most of the agriculture in dry climates will continue to depend on natural rainfall as the proportion which can be irrigated in the near future is relatively small and in any case presents very distinct and specialized problems.

Systems of Agriculture

The type of machinery needed on any agricultural holding is decided by the system of agriculture in use and only its size by the scale of the enterprise. This is clearly seen in hot dry climates where high rates of evapotranspiration coupled with limited and ill-distributed rainfall, falling often in intense storms, dictate a specialized form of agriculture if economic crops are to be grown with any certainty and regularity. Soil and water conservation are of the utmost importance and the success of mechanization in such areas often depends on how successfully the system of farming adopted achieves these.

Rarely is efficient mechanization a matter of finding a machine to reproduce exactly what has been done by hand. It would be foolish, for example, to aim at reproducing the shallow cultivation with the hoe which has been satisfactory for hand planting, when the next operation is to be carried out by a multi-row planter or precision drill which requires an even depth of cultivation. Instead it is necessary to find a new way of handling the soil that achieves the same overall result and at the same time makes mechanization as simple and as cheap as possible.

The establishment of a suitable system of agriculture is the first step in successful mechanization and failure to take it can result in the purchase of unsuitable equipment, lower yields, accelerated soil erosion or a combination of all three. In any country contemplating the mechanization of its agriculture, therefore, the first duty of the research services is to establish systems of agriculture which, while suiting the local climates, soils and crops, can be mechanized easily and efficiently.

II. SOURCES OF POWER

The sources of power that can be used as the basis of the mechanization of any given system of agriculture are usually decided by one implement or process in that system. There will often be one or more operations for which the equipment cannot be scaled down beyond a certain point. It is not, for example, possible to plough less than one furrow, pull less than one tine, or drill less than one row. The deciding operation, especially in the semi-arid tropics, will usually be found among the essential soil conservation measures or in the primary cultivations. Planting, weeding, spraying, harvesting, processing and transport can all be scaled down, if necessary, to be within even the capacity of a woman.

In any given system of mechanized agriculture, it is the extent to which it is necessary to move soil that decides the minimum amount of power that is adequate and hence the smallest and cheapest power unit on which the system can be based. The first step, therefore, is to establish what are suitable methods of cultivation for any given pattern of agriculture, climate and district before trying to evolve a suitable system of mechanization. If no cultivations are required and weed control can be carried out with herbicides, any source of power, including hand labour can be used. For light cultivations, animals, a two-wheeled tractor or a light three- or four-wheeled tractor might be suitable; but where it is necessary to carry out heavy cultivations, nothing less than the standard type of wheel tractor of Western agriculture would be adequate.

In hot dry climates, it is unlikely that many stable forms of food production can be maintained without some form of cultivation, if only to provide for soil and water conservation: with no tillage, infiltration rates can be

* Head of Cultivation Department, National Institute of Agricultural Engineering, Silsoe.

much reduced.[1] With suitable initial land preparation to prevent surface water movement by terracing or bunding, for example, it might be possible to grow some tree or plantation crops using only herbicides or repeated cutting for weed control. The important operations in such a system would then be spraying, mowing, fertilizer distribution and transport: all of which can be carried out with any source of power which the farmer can afford.

Except in pastoral areas, most forms of agriculture in semi-arid areas are based on food and cash crops which have at some time been grown by hand methods. This suggests that light cultivations can be used and that mechanization should be possible with animals and the lightest form of tractor. It is unlikely, however, that such systems of cultivation, evolved under conditions of low power availability, will always be the best. Higher or more consistent yields may come from much heavier operations to encourage water infiltration and soil conservation—like sub-soiling or ridging—which call for more power and higher drawbar pulls than can be provided by animals or light tractors. A good example of this is the system of cultivations based on tied ridges and sub soiling evolved in East and West Africa where it has given greatly increased yields in districts of low rainfall.[2]

Such new types of tillage should, however, be thoroughly tested by controlled experiments over a number of years before being widely adopted. There are many examples of cultivation methods, that have been successful with tractors elsewhere, proving to be quite unsuitable when introduced into a hot dry climate. In one arid desert region with light rainfall, for example, the traditional method was to use a camel drawing a spike-shaped tine to make shallow furrows for planting seed and to leave the soil in between uncultivated. When land in the same area under identical conditions was ploughed by a tractor with a 3-furrow mouldboard plough and then harrowed and drilled, the yield was reduced.[3]

1. Animals

Animal draught appears to be an attractive source of power for many countries where sufficient land is available to provide their food and where pests and diseases are not a problem. In the West Indies, for example, the area of land which can be cultivated is so small in relation to the population that little or none can be spared to feed draught animals, and in parts of Africa the presence of the tsetse fly prevents their use on grounds of disease. Where they can be used, however, animals have not always proved as suitable a source of power as was hoped. The capital cost of a team is often much greater than expected when animals, harness, and implements have been paid for: a recent paper puts the cost in Africa as high as £125.[4] The amount of work that they can do is often restricted because they are small and ill-fed and the animal-drawn equipment available is very primitive.

In spite of these disadvantages, there are many relatively thinly populated semi-arid areas where progress in mechanization could be made by introducing animals and sound implements for them. So little work has been done in this field by engineers in the past that there are at least three ways in which the performance of animals as a source of power in agriculture can be improved. In the first place, it seems likely that the output of animals could be significantly increased by attention to the design of harness. Anyone who has worked with horses in temperate agriculture will know how much their performance depends on the fit and comfort of their harness. An ill-fitting collar which produces sore shoulders, for example, much reduces the pull that they are willing to deliver throughout the working day. It seems inconceivable, therefore, that the crude wooden yokes (Fig. 1), universally used in the tropics, could not be improved in design and by the use of modern materials. Work in Japan has already suggested that the wooden bar across the forehead or the wooden member on the neck may not provide the best way of transmitting a force from the animal to the implement[5] and it is likely that lightweight collars or yokes moulded to the shape of the animal from a material like fibreglass and provided with a resilient lining might further improve performance.

A second profitable line of approach might be research into the factors affecting the draught of soil engaging tools in dry tropical soils. There is ample evidence in temperate agriculture that the design of tines, for example, can have an important effect on the force required to move them through the soil.[6] When so little power is available from animals, it is very much more important than with tractors to make sure that it is used efficiently. A reduction of 20 lb in the draught of a plough body, for example, can represent a saving of as much as a quarter of what a poorly-fed small bullock is capable of producing all day but is an insignificant proportion of what is available from a tractor.

A third source of improvement might be found in the design of animal-drawn implements as a whole. In principle, animals at work all day in hot climates should be required to pull or carry the minimum amount of weight. The most successful primitive implements have usually been extremely light single-purpose tools like the plough in Fig. 2 with no parts not required for the job in hand. Recently, more universal implements have been developed based usually on a frame carried on a pair of wheels to which a number of different attachments can be fitted, often including a seat[7] (Fig. 3). Thus in ploughing, for example, instead of the beam, body and handle of the primitive plough, which can be easily carried by one man, the animals are called upon to pull along all day in the hot sun a pair of wheels and a good deal of very lightly stressed metal which are quite unnecessary for the operation of ploughing. A much more logical approach is to base the design of a universal implement on the beam and handle of the plough to which a range of tillage tools, including a plough body, ridging body, tines, a planter unit and hoes can be fitted as required for field work[8] (Fig. 4). Large wheels and an axle to take a cart body could be added only when needed for transport; but it might well be more convenient and not very much more expensive to consider a cart as a separate item.

2. Tractors

The successful mechanized agriculture in hot dry regions of the more advanced countries shows that modern tractors are a satisfactory source of power. The problem of equipping small farmers has been solved there by a supply of sound second-hand models at reasonable prices and, backed by an efficient dealer network, the necessary experience to maintain them on the farm. None of these can exist or be created quickly in countries which are just embarking on the mechanization of agriculture, so the problem there becomes one of finding satisfactory types of tractor which small farmers can afford to buy new or ways of making available to them the services of those types which they cannot afford to buy. This second solution involves the creation of contract hire services, schemes for co-operative ownership or the establishment of local contractors all of which are outside the scope of this paper. On the assumption that standard wheel tractors are satisfactory for dry land farming, it is only those special types which might be within the means of small farmers that are examined here.

Two-wheeled or walking tractors appear, at first sight, to be the obvious choice for the small farmer because their first cost is not very different from that of a team of trained oxen and their equipment. They have proved, however, to be of limited value in hot dry countries, chiefly because they are restricted as to the type of primary tillage which they can carry out. Their small wheels and light weight means that the pull which they can produce is often less than that of a pair of oxen and so only the lightest form of cultivation is possible with them. The alternative of using their engine power to drive some form of rotary cultivator, to avoid transmission and traction losses is not always satisfactory. The type of tillage carried out may be unsuitable from the point of view of soil and water conservation, soil conditions in dry climates may severely restrict the occasions when a light rotary cultivator will work efficiently and the rate of blade wear may be so high that maintenance costs are prohibitive. The chief role of two-wheeled tractors in tillage, therefore, is to carry out light weeding operations which are not the limiting factor on many holdings and may in any case be taken over by herbicides in the near future. It is true that walking tractors with suitable attachments can be used efficiently for light work like mowing and spraying; but these are rarely the operations which limit the amount of land that a family can farm efficiently.

Apart from such limitations, current types of two-wheeled tractors have not always proved to be completely satisfactory in hot dry climates for other reasons. They are often very tiring to use, and since they can easily exhaust a strong and well-fed operator, using them for a full day for cultivations in a temperate climate, they are often very unpopular with operators in a hot dry one. Their small air-cooled engines, too, have not always proved to be as reliable in the tropics as in temperate zones and in some cases dust from dry abrasive soils has led to very high rates of wear.

Since two-wheeled tractors do not appear to have provided the source of power required in hot dry climates over the 20 years or so that they have been tried, it is logical to think of scaling down and simplifying the much larger three- and four-wheeled tractors which have proved satisfactory so that they come within the reach of the small farmer. Unfortunately, as the size is reduced, the cost of a tractor does not fall in proportion. In Fig. 5 the cost of a number of current British models has been plotted against their engine horsepower to illustrate this point. It will be seen that even the smallest and simplest tractor, a model with a single cylinder air-cooled engine costing about £430 is still likely to be beyond the means of most of the small farmers in the semi-arid tropics and extrapolation suggests that even a 1 hp tractor would cost about £400. The general conclusion must be, therefore, that unless and until social changes bring about a different pattern of farming, the most likely sources of power for these areas will be animals or standard wheel tractors made available on hire or by co-operative ownership, unless a completely different and much cheaper type of tractor can be developed.

III. CULTIVATION AND PLANTING

Soils in hot dry climates often have a poor structure and low permeability, so that rainfall runs off readily. High evaporation rates are usual and further reduce the water available for crops. Cultivations must, therefore, prevent water movement on the surface, encourage infiltration and control weeds at all times while providing a seedbed in which crops can be readily established. The value of crops which can be grown in dry climates is usually low and so there is little money available to spend on cultivations. Further, there is little evidence that tillage beyond the minimum required to achieve these ends is of any benefit[9] and much evidence that more tillage can increase the risk of water loss and soil erosion by wind and water.[10] Sound cultivation in the semi-arid tropics, therefore, is usually a matter of carrying out the minimum number of operations using the minimum amount of the simplest equipment.

1. Cultivation on the Flat

Because most standard equipment is designed for work on the flat and allows the simplest and most flexible systems to be used, this form of cultivation would normally be chosen whenever slopes, climate and soil conditions permitted. The dangers with mechanized cultivations on the flat are that they might break down the soil so finely that it washes or blows away, bury plant residues so completely that the surface rapidly becomes relatively impermeable under rainfall or, in some conditions, create below cultivation depth a dense layer or pan which holds up water movement down the soil profile. For these reasons the mouldboard plough or the standard rotary cultivator of temperate agriculture have little or no place in dry-land farming. Disc implements have the advantage that a good deal of any trash on the surface is retained in or near the surface, but if they are used frequently and at high speeds they can cause excessive soil pulverization. Such unwise use of discs may in extreme cases produce what amounts to a layer of dust above compact soil which does not readily admit water, so that the surface soil is easily washed or blown away.

Dry land cultivation on the flat, therefore, is usually most safely based on some form of tined cultivation for the primary tillage operation. Plant residues are retained in or near the surface, water enters easily and the typical cloddy and slightly ridged surface produced is resistant to erosion by wind and water. In principle, such a system is very similar to the stubble mulch farming of North America which has been shown to reduce surface run-off and soil loss.[11] Under many conditions, however, it may not produce a suitable environment for the efficient planting and ready establishment of crops without some further cultivation which will usually be undesirable because it reduces the soil and water conservation properties of the tilth and because it costs money.

Where basic tillage by tines is not an adequate seedbed preparation, it is possible that an adaptation of what has been called till-planting[12] might be the best way of providing what is required. In this system cultivation is carried out on cultivated or uncultivated soil only on the line of the rows as the crop is planted. The land in between the rows is not cultivated further until weed growth makes inter-row cultivation necessary. In crops grown in wide rows in dry areas, a special form of this strip tillage, known as wheeltrack-planting[13] because the planter are set to follow the tractor wheels, might be of value. The further cultivation and consolidation required is carried out by the tractor wheels and the shallow ruts that they form gather any water which does move on the surface into the vicinity of the young plants.

Suitable equipment for tined cultivation with animals and three- or four-wheeled tractors is available. Two-wheeled tractors cannot be considered suitable for such an operation because their low weight precludes them from providing sufficient drawbar pull for most conditions. Equipment for on-the-row tillage and wheeltrack planting, too, has been developed in North America for standard wheel tractors. The need is for the development of similar equipment, probably in the form of attachments to existing planters, to suit small tractors and animals.

2. Cultivation on the Ridge

All systems of ridge cultivation have the advantage that they can be made to incorporate soil conservation measures that are effective in many situations. They are often, therefore, very suitable for dry climates where the low value of the crops that can be grown cannot pay for the separate soil conservation measures that would be needed for safe cultivation on the flat. Where rainfall intensity is normally low and soil permeability high, very wide low ridges, often known as broad-based terraces, have proved adequate.[14] But where very heavy rainstorms occur and soils can become impermeable, much closer and higher ridges with dams or ties across the furrows at regular intervals (Fig. 6) have provided the best way of combining soil and water conservation with cultivations. Extensive trials of tied ridge systems of cultivation in East and West Africa have established that they usually give higher yields than flat cultivation in areas of marginal and ill-distributed rainfall, except in exceptionally wet seasons. All necessary agricultural operations up to harvesting can be carried out with a toolbar and suitable attachments so that the capital outlay on equipment is low. The trials have shown that standard attachments are suitable for most operations; but that it has been necessary to develop the special tieing units (Fig. 7) and either special ridging bodies or special tine attachments for standard types.[2]

In any form of cultivation based on ridges and where the furrows are not used for irrigation, it is most important that the furrow bottoms should always be as permeable as possible: this is especially important in climates where rainfall is the limiting factor. The points or shares of standard ridging bodies or Lister bottoms all smear the furrow bottom to an extent which reduces permeability on most soils. To this effect is added that of the tractor wheels, which always run in the furrows, and so special precautions against smearing and compaction are necessary. On the easier soils and on those which do not readily become impermeable, all that is usually needed is a tine mounted behind each ridging body and set to run 2 to 3 inches below the furrow bottom. Where conditions are more difficult, periodic deeper tined cultivation may be required either as a separate operation or combined with ridging. For the latter, special types of wing or mouldboard attachments have been developed for heavy duty tines as in Fig. 8. The height at which the wings are bolted to the tine is adjustable to allow for different depths of cultivation below the furrow bottom.

A typical system of tied ridge cultivation might start from the flat by ridging and tieing in one operation on the contour or in straight-sided strips as close to the contour as practicable. Whenever possible, it is of advantage to carry out this operation in the dry season or as early in the rains as possible in order to create the best surface to receive and conserve rainfall. When enough rainfall has fallen to ensure germination, or even before rain under some conditions, planters would be used on the toolbar to sow the crops in single or multiple rows on the ridges with tieing units to rebuild the ties in the two furrows damaged by the tractor wheels. Inter-row cultivation would be carried out by ridging bodies or bedder sweeps, which cut off the weeds between the rows and smother those in the row, and tieing units. After harvest, ridging bodies would be used with tieing units either to split or rebuild the old ridges and tie the furrows ready for the planting of the next crop. If subsoiling were required it would be carried out at this stage in the furrow bottoms or on the line of the ridges before re-ridging.

IV. POST-PLANTING OPERATIONS

1. Inter-row Cultivations

When the crop has been planted, the main aim must always be to maintain effective weed control because with a marginal water supply none can be spared to grow weeds. At the present time it is usually cheaper to control weeds in growing crops by cultivation than by herbicides; but this may not always be the case. Thus, where mechanized crop weeding is the aim, it is essential to adopt planting in accurate rows in place of the more common broadcasting or very variable rows of primitive agriculture. Inter-row cultivations in the absence of weeds have been shown to have no benefit on crop yields and may even depress them by damaging the root systems of crops or by causing water loss.[15] For this reason, only the minimum amount of the lightest cultivation needed to kill all the weeds is normally required and no cultivations at all if a herbicide costing no more is available. The exceptions occur on tied ridges, where inter-row cultivation may be needed to maintain a surface that is safe against water movement, and on land which caps easily where surface cultivation has been shown to increase infiltration. Normally, therefore, inter-row cultivations call for the standard light tined equipment which is within the capabilities of any source of power available and will be much more effective in dry climates than in the temperate zones.

2. Post and Disease Control

In all forms of agriculture, the trend is towards an increased use of chemicals for the control of pests and diseases as well as for herbicides and dry land farming is no exception. The tendency is, too, for these chemicals to be used at lower rates and for their efficiency to depend on the accuracy with which they are applied as a spray, as a powder or as granules. The general demand, therefore, is for more accurate equipment for their application and this poses special problems in remote areas where the users may not be very experienced or able to call readily on trained advisers or good service facilities. The problem facing agricultural engineers, therefore is that of designing simple, robust and reliable sprayers and applicators capable of a reasonably accurate performance without calibration and adjustment over long periods. The characteristics of nozzles, pumps, regulators and metering mechanisms should change as slowly as possible with use and settings for application rates be made as simple as possible. If such equipment can be provided, the smaller farmer in developing countries need not lag behind others in exploiting past and future developments in herbicides, insecticides and fungicides which can go a long way towards increasing crop production and making cropping more reliable in marginal areas.

V. HARVESTING

The mechanization of harvesting is generally not so important in dry climates. It is an operation which comes at the start of a long dry season, so that standing crops do not deteriorate rapidly, as in the humid tropics or temperate climates, and do not require artificial drying before storage. There is, too, rarely enough moisture to grow rain fed below-ground crops like groundnuts, which might be difficult to harvest from hard dry soil. Hand harvesting methods, therefore, are likely to be adequate for small farmers at least until they have successfully mechanized operations like primary tillage and planting where speed and timeliness often have an important influence on crop establishment and yield.

VI. SUMMARY AND CONCLUSIONS

1. Since the agricultural system adopted decides the type of machinery required, the first step in successful mechanisation in hot dry climates is to establish a sound system which can both be mechanized easily and will ensure effective soil and water conservation.
2. Often in essential conservation measures or basic tillage there is one operation which cannot be scaled down below a certain point and this decides the smallest source of power that can be used as the basis of mechanization.
3. Where no tillage or soil conservation is needed, all sources of power including hand labour can be used; where light cultivations are adequate, animals or walking tractors can be employed; but if heavy operations like subsoiling are necessary nothing less than standard wheel tractors will be satisfactory.
4. The performance of animals as a source of power could be improved by attention to the design of harness, research into the performance of tillage tools in tropical soils and improvements in the design of animal-drawn equipment.
5. It is unlikely that sound mechanized agriculture in hot dry climates can be based on walking tractors or that standard wheel tractors can be scaled down in size and price to be within the means of most farmers.
6. Suitable types of cultivations on the flat are likely to be founded on some form of minimum tillage including probably a combination of stubble mulching and strip tillage.
7. For many conditions in the semi-arid tropics, tied ridge cultivation will have advantages over other forms, because of its superior soil and water conservation properties.
8. In developing countries there is a need for simple, robust and reliable sprayers and applicators capable of accurate performance without calibration and adjustment over long periods.
9. In climates where harvesting occurs at the start of a dry season, there is often less need for speed than in the humid tropics, or temperate zones and so less reason to introduce harvesters in the early days of mechanization.

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Fig. 1

Fig. 2

Fig. 3

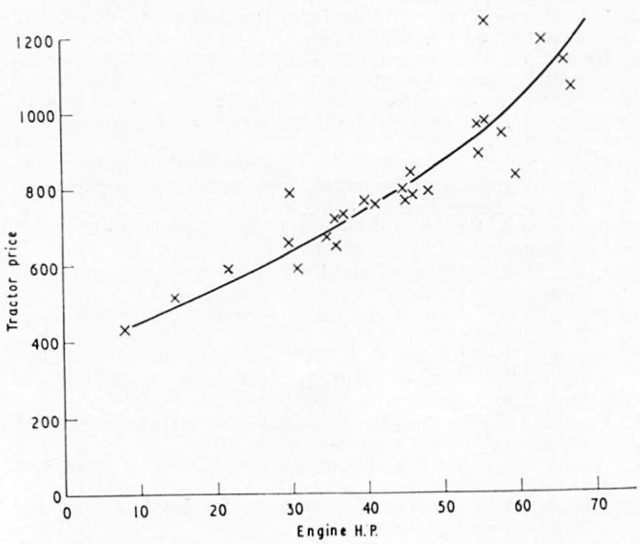

Fig. 5

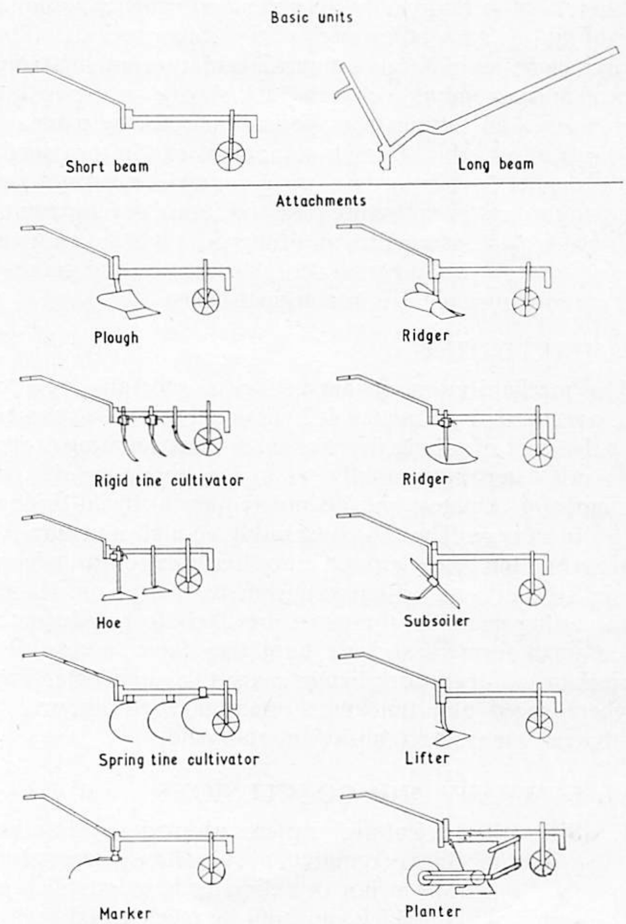

Fig. 4

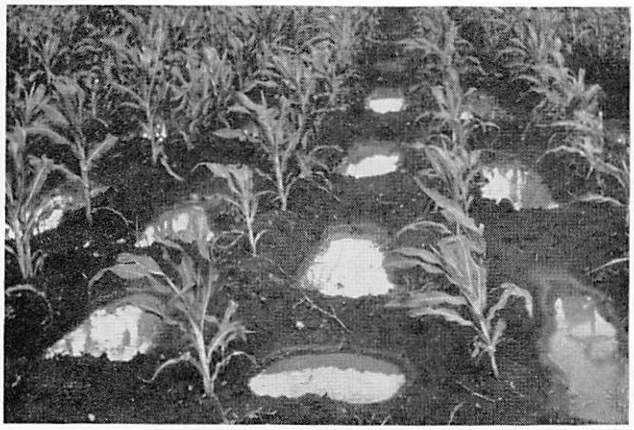

FIG. 6

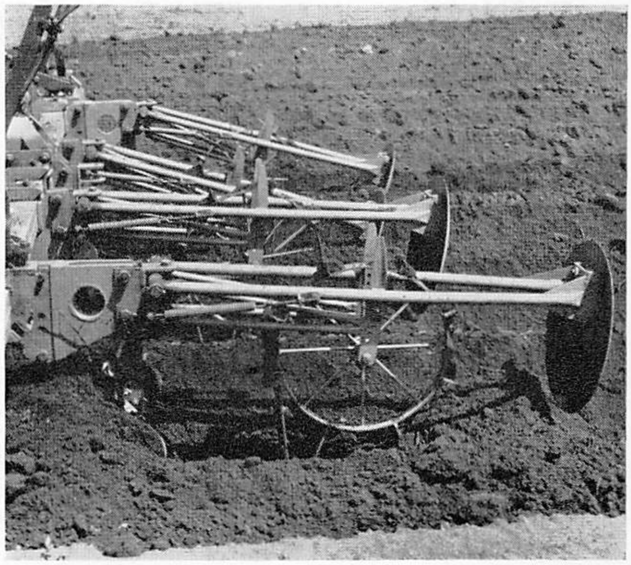

FIG. 7

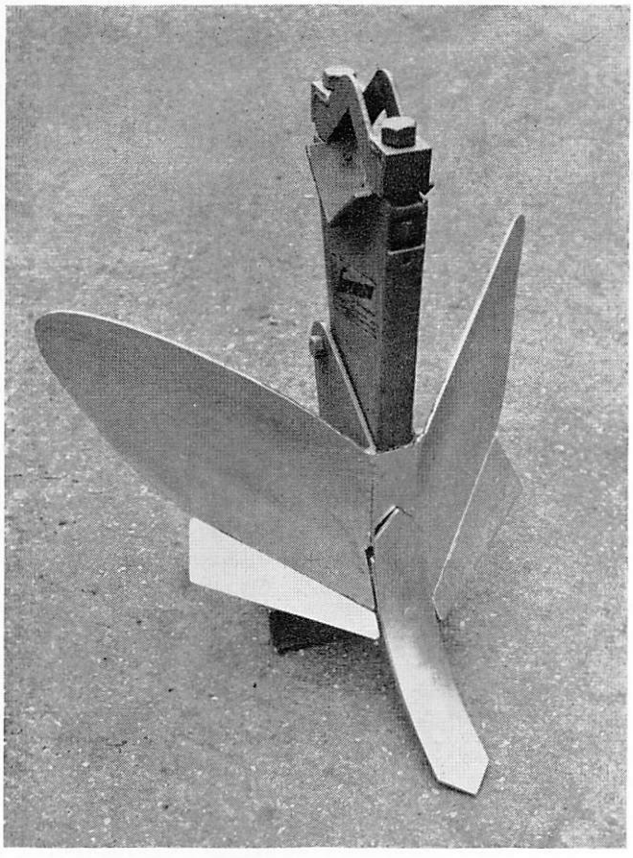

FIG. 8

THE CONTRIBUTION OF THE AGRICULTURAL ENGINEER TOWARDS DEVELOPMENT OF AGRICULTURE IN THE SUDAN

by B. P. POTHECARY, MA, M SC, MEM ASAE MI AGR E,*

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SUMMARY

An outline of the geographical situation and agricultural potential of the Sudan has led to a more detailed analysis as to the present place and future part to be played by mechanization. There are many problems to be overcome if agricultural machinery usage is to be expanded, but on the other hand the Sudan has considerable natural advantages and has gone a long way towards resolving some of its problems. Overall she is more favourably placed than many other developing countries.

The important role of the Agricultural Engineer has been demonstrated and an analysis made as to where and how he can contribute towards sound agricultural development. There is room for continued professional interest by the United Kingdom in countries such as the Sudan, as for several years yet they will not be in a position to carry the whole burden of development themselves.

Finally, the present extent of machinery usage has been studied in some detail and mention made as to where the Agricultural Engineer must bring his knowledge and experience to bear if future requirements are to be met. In general there is a dual trend, on the one hand towards extending the use of machinery in certain areas and on the other towards the introduction of more advanced techniques and equipment in well established areas.

INTRODUCTION

The Sudan covers a vast area of land in N.E. Africa lying between latitudes 6 N and 22 N and stretching from the Red Sea to the heart of the Continent. It ranges from arid desert in the North through flat dry open savannah in central regions to tropical forest and swamp land in the South. There are few ranges of mountains outside the Red Sea hills, the central Nuba Mountains, and the Jebel Marra area in the West. Flat or slightly undulating land predominates.

The river Nile dominates the country. Starting as the White Nile in Uganda it flows North through the country into Egypt. At Khartoum it is joined by the Blue Nile which carries the seasonal flood water from Abyssinia. Each of these major rivers has a number of important tributaries. Rainfall is virtually nil in the North but South of Khartoum it becomes adequate to support annual grasses and grain crops in good seasons. Further South seasonal rainfall is adequate for a wider range of crops and in the extreme South tropical conditions prevail. In all areas it is either very hot and dry or hot and damp throughout the year. Overall population density is low though in certain localities, such as around El Obeid, pressure on land has been great. The absence of perennial water supplies over large areas of the central plains accentuates the problem of local overcrowding.

AGRICULTURE IN THE SUDAN

A well established pattern of Agriculture has evolved in the main areas of the Sudan though development in the South has, regrettably, been retarded in recent years. In the North, crops can only be established under irrigation from the river but in the Central region there is a distinct division as between:

(*a*) Irrigated areas

(*b*) Rainfed areas.

To some extent these overlap in the more Southerly part of the region but, mainly, irrigation has been confined to marginal and sub-marginal rainfall areas along the rivers whereas away from the rivers lie the millions of acres of land with adequate rainfall to support annual crops.

Over a large part of the whole area, whether irrigated or not, heavy clay soils predominate, with uniform characteristics. They are strongly alkaline with 55% to 65% clay fraction and have a high co-efficient of expansion and contraction on wetting and drying. When wet they are extremely unstable, plastic, and impermeable and when dry are compact and hard but can break down into fine non-abrasive dust if overworked. The pattern is somewhat different in Western areas where coarser sandy/loams predominate. Again the irrigated riverain soils in the North are much lighter in texture.

Extra long staple cotton is the dominating crop and revenue earner in the irrigated areas with dura (sorghum) fulfilling a similar role in the rainland areas. In some areas though such as the Nuba Mountains, rainfed short staple cotton is well established. Dura is also grown on irrigated schemes as a local food crop. Groundnuts are of major importance in the Western rainland areas, and on the more sandy soils, and are an important secondary cash crop in the irrigated areas especially the Gezira. Wheat is a traditional crop of the Northern provinces along the river but more recently it has also been introduced into the Gezira area. Other important crops are sesame in the rainlands, lubia fodder in the Gezira, and vegetables and fruit in many areas where perennial water is obtainable.

The areas under crop, whether rainfed or irrigated, are extensively rather than intensively cultivated and as the farming pattern is based on cash crops such as Cotton, Dura, and Groundnuts, and linked with widespread livestock husbandry, a picture emerges of a healthy and relatively prosperous agricultural pattern.

In particular, a most significant contribution has been made in the field of planned settlement schemes such as

*Agricultural Engineer, Sudan Gezira Board.

the Gezira Scheme where tenants have been successfully growing extra long staple cotton and other crops, under irrigation, for a period of 40 years or more. The irrigated area within the Gezira now amounts to some two million acres and this is supplemented by other smaller schemes and private pump schemes run on similar lines elsewhere along the banks of the Nile.

On the other hand there are the millions of acres of clay plain with adequate annual rainfall for crop production. Part of these have already been utilized for dura (sorghum) growing but vast areas remain for development. In both irrigated and non-irrigated areas a great deal of research work has been done on soils, crops, growing methods, fertilizer requirements, pest and weed control measures, etc., and the realization of much of this work in practice can only be based, in the case of the Sudan, on systems of agriculture involving a greater or lesser degree of mechanization.

At this stage, therefore, perhaps it would be as well to summarize, as follows, those factors favourable to the development of mechanized agriculture:

1. a relatively low population density in areas of high potential fertility
2. large areas of land where rainfall, soil, and topography are favourable to low cost machinery operations
3. an abundance of water to irrigate drier areas
4. the relative absence of difficult land clearing problems
5. land tenure systems which can be adapted to the requirements of mechanization
6. flat or slightly undulating topography, leading to high machinery outputs without, in many cases, necessitating costly soil conservation measures
7. large areas of workable, low abrasive soils with opportunities to practice minimum tillage techniques
8. crops of proven return with an assured market especially in the irrigated areas, which can provide the economic basis for mechanization
9. long reliable dry season in which to control annual and perennial weed growth

Furthermore the irrigated areas have been laid out in a uniform pattern of holdings which are suited to mechanical operations.

All these factors add up to a stituation whereby extensive mechanization is essential if the Central rainlands are to be further developed. On the other hand intensive mechanization is likely to be progressively introduced into the irrigated areas due to intensification of cropping and the increasing cost and shortage of seasonal labour.

THE PRESENT EXTENT AND FUTURE PLACE OF MECHANIZATION IN AGRICULTURE

The factors favourable for the growth of mechanization have already been outlined but, in fact, a good deal of progress in this field has already been made.

Initial developments were stimulated by the Ministry of Agriculture working mainly in the rainlands and the Gezira Board in the irrigated areas. During and immediately after the second world war extensive dura growing was started in the Gedaref area based on mechanization and direct labour. Although not a success financially, a great deal was learnt as to the type of machinery required and mode of operation not only for extensive grain growing but also for one or two other potential crops. This work was supplemented and intensified in the 1950's at Tozi on the West bank of the Blue Nile in a more favourable rainfall area, where a wide range of crops could be grown. In the irrigated areas the Gezira Board (then Sudan Plantation Syndicate) had long since used bulls for ridging and at an early date introduced steam cultivators for land preparation and perennial weed control. These were later replaced by wheeled tractors to do the ridging and heavy crawler tractors to carry out perennial weed control using deep straight blades.

At the present time tractors and agricultural machinery are extensively operated by the Ministry of Agriculture on agricultural stations and schemes under their control; by the Gezira Board; by Contractors in the Gezira, private schemes and new development areas; by Co-operatives mainly in the Gezira; and by Private Owners on their own schemes principally in the rain lands. Thus there is a great variety of organizations owning and operating machinery, though the bulk is in the hands of private owners and contractors.

The accent, generally speaking, is on extensive operation with high outputs per machine and therefore the range of operations carried out is comparatively small and confined mainly to land preparation and weed control with seeding in the rainlands. In irrigated areas a simple ridge and split ridge system is practiced and wide disc tillers are used in the rainlands for all operations including seeding. Thus the equipment most commonly seen is the tractor with toolbar and ridging bodies in the irrigated areas and with wide level disc tiller and seedbox in rainland areas.

Other equipments used on a reasonable scale are specially designed deep straight blades for perennial weed control in the Gezira and combine harvesters for wheat, again principally in the Gezira but also at Khashm el Girba, and to a limited extent for dura in the Central rainlands. Disc ploughs and offset disc harrows are widely used in the new irrigation areas such as at Khashm el Girba where weed growth is considerable. A small number of land planes are in use but tractor trailers are rarely to be seen as they cannot compete with lorry transport on the one hand and the ubiquitous donkeys and camels on the other. Crop protection is carried out almost entirely from the air and herbicides are not yet in common use. Thus although the present level of machinery usage is extensive it is definitely restricted in variety very largely, as we shall see, due to ignorance of new techniques and their place in the system of agriculture.

As regards the future, a good deal of investigation has been carried out in all areas using more advanced equipment and techniques. Mechanized fertilizer spreading, land levelling, cultivation methods, weed control, specialist crop harvesting and processing, planting, and cotton picking have all received attention. In many cases new mechanized methods have been developed to an extent where they are ready for wide adoption. There is a need for planned extension and education services, and for ways and means of financing purchases. Taken together these factors currently form a large part of the current limitations to the wider utilization of tractor power.

The development should be intensified and problems associated with furthering mechanization solved is clearly shown in the plans for the utilization of Roseires dam water and the development of the rainlands. All plans rely on extensive use of machinery to fulfil output targets and reduce reliance on seasonal labour.

PROBLEMS TO BE FACED UNDER A POLICY OF EXPANSION IN AGRICULTURAL MECHANIZATION

Already some of the problems encountered in expanding mechanization have been touched on in the introductory paragraphs of this paper, but a fully comprehensive list might read as follows:

1. The high cost of machinery and spares due to long lines of communication, both external and internal, with producer countries.
2. The high cost of supplying and servicing machinery owing to the scattered centres of agricultural production and their distance from major town centres.
3. The absence, in some cases, of the right type of machinery to carry out certain operations together with the need to adapt other proprietary equipment before it can be considered suitable for Sudanese conditions.
4. The lack of suitable varieties of one or more important crops to make mechanical harvesting and handling possible without recourse to expensive, complicated, and low output machinery.
5. A scarcity of expertise at all levels due, partly to lack of training facilities, and partly to competition from other more attractive sectors of employment.
6. The comparative absence of extension services to bring proven machinery techniques to the notice of the user and convince him of their advantages.
7. The small number of reputable and conscientious machinery importers prepared to invest in a proper system of supply and service and to give adequate coverage of the country.
8. The relative inexperience amongst co-operatives and other enterprises when undertaking machinery ownership and operation.
9. The concentration of available private capital for the purchase of new machinery in the hands of a few people more interested in immediate profit rather than achieving a high standard of operation and proper integration of machinery into the farming system.
10. The relative lack of capital available to the better type of entrepreneur who might otherwise be capable of taking advantage of up to date methods.
11. The need for planning, in new areas to take account of mechanization, and in the old established areas to ensure successful introduction of new mechanized techniques.
12. The relative absence of reliable cost and performance data on which to base new operations.

The foregoing list of problems is formidable in itself but not, I submit, insurmountable in the case of the Sudan in view of the natural advantages which more than offset the disadvantages. In other developing countries many problems of a far more fundamental nature are likely to be encountered in addition to those mentioned above as being applicable to the Sudan. Some of these are:

(*a*) overpopulation and an abundance of cheap, hand labour
(*b*) land tenure and hereditary systems leading to excessive fragmentation of holdings
(*c*) the absence of high value crops and/or suitable agricultural systems onto which mechanization can be grafted.
(*d*) the high cost of land clearing
(*e*) terrain, soils and rainfall intensities which demand expensive soil conservation measures
(*f*) over-riding agronomic problems such as crops unsuited to mechanization
(*g*) conditions conducive to a high rate of weed growth, and pest and disease incidence which are uneconomic to control in relation to intrinsic crop values.

Thus the Sudan is fortunate, in many respects, and must surely come high up on the list of developing countries where mechanization could succeed.

THE ROLE OF THE AGRICULTURAL ENGINEER

Many of the factors involved in expanding mechanization in agriculture are beyond the direct control of the Agricultural Engineer. For instance, he can only have a marginal influence on the crops and environment under which they grow. He has no control over the allocation of funds for agricultural development. He can, however, influence, through his efforts, the direction and pace of development and give a clear lead as to where funds should be allocated to viable mechanization projects, or to the intensification of mechanization in established areas.

Thus in a country such as the Sudan the Agricultural Engineer may act in any one or more of the following capacities:

1. as a consultant
2. as a research/development engineer
3. as a specialist in application and organization of mechanized projects
4. as an extentionist
5. as a manager or engineer of a large distributor of agricultural machinery
6. as an educationalist or instructor
7. as a specialist in the co-operative or joint use of machinery

In each of these spheres a significant contribution can be made from Agricultural Engineers from outside the Sudan who are employed by national, international, or commercial concerns with interests in the Sudan. The extent of their contribution will depend on a thorough appraisal of the special needs of the country, the capacity of local resources to resolve their own problems, and the willingness of the country to accept disinterested outside help. Commercial concerns can and are making a significant contribution but cannot always expect to reap an immediate financial reward for such help. However, if their efforts are spread over a number of similarly placed countries then the experience gained as to the real needs of these countries adds up to a considerable field for exploitation. The paramount need of any Agricultural Engineer seeking to contribute to the needs of countries such as the Sudan is a highly professional approach. Too much of the British effort in the past has been in the hands of people, albeit well meaning, who have neither the proper background or experience of the peculiar needs of overseas developing countries.

THE CONTRIBUTION OF THE AGRICULTURAL ENGINEER

The role of the Agricultural Engineer in a country such as the Sudan has been outlined, and it is now possible to analyse his contribution more closely.

In the first instance he should be closely associated with the planning stage of new developments or extensions to existing projects. Once given the broad basis and aims of such developments, he can indicate the advantages and disadvantages of using machinery and the extent to which it should be introduced. Furthermore, he can bring his experience to bear on land clearing problems, soil conservation works, field layout, irrigation systems and their maintenance, land levelling, crop rotations to suit mechanization, number and type of tractors and equipment, workshops organization and field maintenance, planning of storage and processing installations and training facilities. His contribution, at this stage, is normally as one of a team working together to produce a viable plan for investment.

Then the Agricultural Engineer has a significant contribution to make at the implementation stage. As a Development or Research Engineer he may be employed to devise new techniques involving machinery and to ensure that available machinery is capable of giving optimum performance under local conditions. All too often machinery designed for highly developed temperate agriculture has proved unacceptable or too complex for less developed tropical areas where conditions are entirely different, returns per acre are lower, and labour is less skilled. In addition, it is the Agricultural Engineer's task to ensure that machinery is properly organized in the field and economically operated. In the past, promising schemes have failed due to lack of proper appreciation as to the importance of machinery management. A high degree of skill is required on a day-to-day basis to ensure continuous and efficient operation.

Then again the Agricultural Engineer has an important role within extension services. No amount of planning or research and development will, of themselves, ensure success at ground level. The actual introduction phase is all-important whatever type of organization is the eventual end user. This particularly applies where owner-operators have been encouraged, with the backing of credit facilities to purchase and work machinery not only on their own holdings but also on adjacent land. Careful demonstration and intensive training of supervisors and drivers is required. The necessity for maintaining continuity in field work, ensuring timely repairs, and maintaining a simple costing system should also be instilled. There is also room for more formal extension techniques directed at groups of owners, the larger contractors, and members of the machinery co-operatives.

As a senior member on the staff of a large distributor, the Agricultural Engineer can make a major contribution, not only in the day-to-day organization and direction of sales and service, but also by encouraging his more forward-looking and progressive customers to innovate and utilize a greater variety of machinery. In many cases a great deal more will be required of the distributor as he will have also to exhibit, demonstrate, and sometimes modify standard machinery to suit local conditions. Then, too, he may have to carry the burden of introduction and train personnel of all grades in the new techniques involved. In all this work he must of course carry the local Government Agricultural services with him and secure their co-operation and interest if he is to achieve success. There are a number of instances in the Sudan where such pioneering work has succeeded and, more generally speaking, the chances of success are greatly enhanced if such work is directed by an experienced Agricultural Engineer from the outset.

In the educational field the Agricultural Engineer, in collaboration with other authorities, should plan and direct specialist training facilities for managerial staff, supervisors, agricultural mechanics and tractor drivers. This field is of fundamental and vital importance to any mechanization programme. Although there are many born operators, the complexity of the tractor driver's job soon reaches the stage where formal training pays off. Properly trained agricultural mechanics are equally essential as the majority of artisans do not normally have any knowledge of the working and setting of agricultural machinery in the field.

As mentioned earlier properly trained supervisors and managerial staff are a basic necessity and the relative absence of training facilities for this class of personnel is a feature not only of the Sudan but of many other countries. It may be argued that training facilities exist in advanced countries for this class of personnel, but quite often the prevailing conditions there are very different from those encountered in the trainees' country of origin.

AGRICULTURAL MACHINERY REQUIREMENTS OF THE SUDAN WITH SPECIAL REFERENCE TO DESIRABLE ENGINEERING FEATURES

Having established the role of the Agricultural Engineer in countries such as the Sudan it may be of interest to analyse its specific machinery requirements and to highlight desirable engineering features especially where innovation or adaptation is called for. For convenience this analysis has been discussed under the following sub-headings:

Tractors

Land preparation, fertilizer application & planting

Irrigation, levelling and drainage
Weed control
Pest and disease control
Crop harvesting
Processing and storing
Miscellaneous items including reference to local manufacture, hand tools, and animal drawn equipment

Tractors

The main agricultural areas are extensive and remote and therefore the demand is for higher powered yet versatile wheeled tractors which must work for long hours under hot, dry and dusty conditions with the minimum of maintenance. Crawler tractors are only needed for special operations in the Gezira and on the two Sugar Estates.

Under these circumstances special attention has to be paid to cooling systems, bearing sealing, air and fuel filtration, electrical components, wiring and batteries. Steering mechanisms frequently have to stand up to continuous shock loading in the field and tyres are subject to side wall abrasion. Hydraulics need only to be of the simplest design but with provision for operating slave rams as trailed equipment is still in wide use and likely to be for many years. Lift linkages need to be specially robust. Wheel traction devices are hardly required as when soils are too wet they should not be worked. Generally speaking British tractors stand up well to these conditions and the Gezira Board, for instance, owns some 130 wheeled tractors each of which averages 1800 hours of work per annum.

Land preparation, fertilizer application, and planting

Primary land preparation in most areas is designed to make a seedbed, ensure good penetration of early rains, control weeds, and deal with crop residues—in that order of importance.

Thus in irrigated areas, where crop residues are removed or heavily grazed, land preparation is confined to the making and remaking of ridges on which all crops are grown with the exception of wheat. However, where a separate perennial weed control operation is not carried out disc ploughing may be done first. The making of ridges may be done throughout the dry season whereas early rains are required to enable the discs to penetrate in the grain growing areas.

Therefore toolbars have to be extremely robust and bodies should be of the 'middle buster' type. Ideally they should be easily adaptable to remaking the ridges after the crop has been planted. The North American wide level disc tiller has been universally adopted in the rainlands due to its high capacity and versatility. In higher rainfall areas it is incapable of dealing with heavy crop residues and here the heavy duty disc harrow can find a place. Much attention is being given to alternative methods in the irrigated areas so as to improve the standard of ridging, incorporate a specific operation against annual weeds, and to create conditions in which land planes can be used. This would involve pre-watering all land to germinate seedlings prior to cultivation, to be followed by land planing and ridging up from the flat just before planting.

The application of fertilizer, usually nitrogen, is a widespread practice on cotton and occasionally on other crops. It is universally spread by hand, an almost impossible task when 80 kilograms of material has to be spread evenly over one acre. In the Gezira extensive trials have been made with equipment for machine spreading, including application from the air. Research has shown that application at sowing time gives the best results but in practice this would be difficult by machine. However a method of application simultaneous with ridging has been developed, thus providing immediate cover for the fertilizer and reducing the present high rate of loss. A standard pendulum type spreader is front mounted and driven from the p.t.o. by a shaft beneath the tractor and the ridging bodies are rear mounted as usual. This method has been compared with hoppers mounted over the toolbar and also bulk bodies mounted on standard lorry chassis. The latter have a very high output but certain categories of soft land make traction difficult and turning impossible.

The planting of all crops except dura and some wheat is done by hand. Restricted planting seasons, soil conditions, and weather, make it difficult to introduce planters for cotton. But for groundnuts and lubia bean only machine planting will give the high seed rate and plant population necessary for optimum yields. Even for cotton there is evidence that economy in seed use and improved germination may be achieved through machine planting and the labour expended on thinning is reduced. In the rainlands dura is currently sown using seed box attachments for the wide level discs but there is a need for planters where other crops are grown extensively.

Irrigation, levelling and drainage

The construction and maintenance of permanent works is outside the responsibilities of the Agricultural Engineer but semi-permanent field works are very much his concern. The construction of water feed channels and laterals is already carried out extensively by machinery with the exception of the smallest field channels and bunds. In irrigated areas a 'patchwork quilt' system has been long established and experimental work is under way to replace this by more up to date methods based on long furrow irrigation. This is linked to the whole question of land levels and drainage which is currently a major topic of interest especially in the Gezira where the annual yield fluctuations have been partly attributed to incipient water logging and water starvation within the field, particularly during the early stages of crop growth. As an interim step, ways and means of constructing the smallest channels by tractor across the ridges are being investigated, and a comprehensive survey has been instituted to try and pinpoint those areas in greatest need of levelling. The use of land planes without survey is also being looked into. The University of Khartoum, the Ministry of Agriculture and the Sudan Gezira Board have all tried long furrows fed from syphons or wall pipes, and portable channels with valves are shortly to be tested. The aim is to achieve economy in the use of water and to control its application, as well as to facilitate mechanization.

Weed control

Both in the irrigated areas and rainlands the long dry season creates excellent opportunities for weed control and some are killed during routine cultivation. However two serious perennial weeds predominate in irrigated areas and special weed control measures are taken in the Gezira principally against one of them, namely nut grass, (Cyperus Rotundus). Experiments in the 1930's showed that this could be controlled by cutting off its water supply from beneath the nut horizon thus desiccating and killing the nuts and roots. Hence the operation of deep blading which was devised in the early 1950's and replaced deep cultivation. The operation of blades also disturbs the soil and this has a side effect on the extremely tough patches of Couch Grass (Cynoden Ductylon).

Annual weeds within the crop are almost universally dealt with by hand labour, although split ridging immediately prior to planting and late discing help considerably. Inter-row hoeing is hardly ever practised due to irregular planting and ignorance of the technique, thus in the rainlands dura is frequently not weeded at all after planting, leading to reduced yields.

A study of suitable inter-row equipment has been made in the Gezira with the aim of combining weeding with the mechanical re-shaping of ridges after heavy rainfall or irrigation. Several bodies show promise and it is largely a question of proper setting. Herbicides are being evaluated especially for Cotton and Groundnuts and the techniques of pre-emergent band spraying has proved feasible and economical. Soil-incorporated herbicides may also be tried.

Pest and Disease Control

Pest Control work is concentrated mainly on Cotton and carried out from the air. Seed dressing is widely practised on Cotton and some other crops such as Groundnuts. Aerial Spray contractors are well established and provide a complete service for the private schemes whereas field observation and control of operations is carried out by Ministry of Agriculture or Sudan Gezira Board staff in the areas covered by them.

Continuous experimental work is being carried out to evaluate new chemical products and the effect of their inter-action on pest and disease complexes. Recently ultra low volume techniques have been under trial and systemic insecticides are also being tested. The latter would require to be applied by machine co-incident with re-making the ridges around thinning time.

Few other crops are subject to control programmes although Aphids can seriously affect wheat and dura as well as Cotton.

There is, however, one feature of Cotton growing peculiar to the Sudan, namely the extremely stringent measures in force to clean up Cotton plant residues after picking. The almost calamitous losses of crop in the 1930's due to Blackarm and other diseases led to the introduction of these measures whereby every plant was pulled by hand and burnt and the land swept by hand to collect all trash which again was burnt. These practices are still enforced. They are expensive and time consuming and carried out under arduous conditions of extreme heat.

An extensive programme of development work to mechanize this operation was commenced by the Sudan Gezira Board in the 1950's. This work was intensified a few years ago and, backed by British technical assistance, a four row tractor mounted stalk puller has now been designed and built. In addition equipment to mechanize sweeping up has been constructed locally and an attempt is to be made to use flame burners to destroy debris *in situ*. At the same time exhaustive enquiries into alternative permissible ways and means of doing this operation are being made in collaboration with research scientists.

Crop Harvesting

The harvesting of crops mechanically constitutes the largest single field for development in the Sudan. At present only wheat is combined and that only where sizeable areas are grown such as in the Gezira and at Khashm el Girba. No serious technical problems have been encountered. Some dura is combined in the rainlands where dwarf varieties have been introduced, and the heads are stationary-threshed, using a modified maize sheller, in some parts of the Gezira. Otherwise all crops are harvested entirely by hand.

As regards cotton picking, American-made pickers and strippers have been tested by the Ministry of Agriculture on short staple varieties but on slow maturing extra long staple types, which form the bulk of the Sudanese crop, they have however proved unsuitable. Efficient combining of dura is linked to the production and propagation of dwarf varieties although maize attachments for combines have proved capable of dealing with most of the local tall varieties. The latter operation is however complex, slow and uneconomic and in irrigated areas unacceptable to the tenants.

The harvesting of groundnuts from heavy clay soils, both irrigated and rain grown, has received special attention. Acceptable and economic solutions are in sight along the lines of modified American practices. These involve the use of digging blades, side delivery rakes and/or digger shaker windrowers, coupled with stationary pickers or combine harvesters. The cutting and binding of sesame, another important oil seed, has been attempted so as to reduce heavy losses at harvest time. Here again this project is linked to a breeding programme to produce non-shattering varieties.

Forage harvesting could well become of considerable importance as the proper feeding of livestock becomes more widespread. To this end some work has been done in an attempt to mechanize the cutting and baling of lubia (Dolichos Lablab).

Processing and Storage

The ginning of cotton has long been practiced in the Sudan and is a specialized operation carried out by the Sudan Gezira Board, Government, and private ginneries. This is linked to extensive storage facilities for baled cotton both adjacent to the factories and also in Port Sudan.

The processing and conversion of other crops is largely in the hands of private enterprise; a notable example being groundnut handling, decortication, grading and sorting which is in the hands of a number of firms operating in the Kordofan Province, Khartoum, and Port Sudan. The rain grown crop is well catered for but Ashford, the predominant variety in newer irrigated areas, has presented certain problems to the commercial processors. The larger pods are well filled and frequently over-dried samples mean that a very high proportion of splits with skinning occur during decortication. Subsequent processes are also slowed down and the net result is an inferior end product leading to lower prices for what is basically a promising variety otherwise. There is also a somewhat dangerous practice of washing nuts which could lead to aflatoxin infection. As regards oil extraction there are several mills for cotton seed and groundnuts.

Seed production is as yet in its infancy though there is an urgent need for high grade seed for all crops. Propagation is practiced in the Gezira and in selected areas by the Ministry of Agriculture but as far as is known there is no complementary seed selection, grading, and sorting.

The scale of losses due to inadequate storage facilities together with improved storage methods for local food crops have scarcely been investigated. Silos have been installed in Gedaref for dura but otherwise all crops are handled in the sack and swiftly passed into the hands of merchants. That part retained for local food consumption is usually stored in underground pits though raised storage containers are to be seen in some areas. A further aspect of storage is the possible need to protect supplies of fertilizer from early rains, consequent on the recommendation to apply it at sowing time.

Miscellaneous

Mention might be made here of the potential for local manufacture, as already hand tools, including cotton stalk pullers, are made in the Sudan in addition to a wide range of spare parts. There is a national need to conserve foreign currency but it is doubtful whether local manufacture can economically be extended to major items as high grade materials would still have to be imported and some form of quality control would be essential. An extension of the manufacture of hand operated machines would however be possible and the ability of local workshops to make such items has already been demonstrated.

The ample supplies of hydro electricity adjacent to rural areas would seem to indicate early developments in this field. However distances involved are great and centres of population sparse. Under the circumstances the extension of electricity into these areas is likely to be long delayed.

The use of animal-drawn equipment was encouraged from the early days in the Gezira but it has sharply declined in recent years due to competition from tractors and the difficulty of maintaining good bull stocks and finding local villagers interested in this class of work. They are still used to demarcate the lines of field channels and bunds and to a lesser extent for re-shaping ridges.

In other areas only limited use has been made of local animals for field work.

ACKNOWLEDGEMENTS

Thanks are due to my employers, the Sudan Gezira Board, who have allowed me to draw freely on my experience whilst working with them and also to my colleagues elsewhere in the Sudan who have provided me with so much information on activities outside the Gezira area.

Obituary

Dr CORNELIUS DAVIES

Dr Cornelius Davies, D SC, HON MI AGR E, a Past-President of the Institution, died in April 1967. Cornelius Davies joined the Institution shortly after it was founded and was, in succession, a member of Council and Vice-President. When Colonel Johnson, the Founder President of the Institution, retired Cornelius Davies succeeded him as President.

Dr Davies received his training in agriculture and in agricultural engineering in South Africa and served overseas during the First World War, when hew as badly wounded. On demobilization he was appointed lecturer in agricultural engineering and Head of the Department at Wye College. While at Wye he engaged in research and experimental work on spray nozzles and their use in agriculture and horticulture. For this work he was awarded the D SC of the University of London. When war broke out Dr Davies was seconded to the Ministry of Agriculture as Farm Mechanization Adviser on food production and after the war he joined the National Agricultural Advisory Service as Mechanization Adviser to the East Anglian Region. On his retirement from the Ministry of Agriculture he was seconded to F.A.O. and did valuable work overseas on mechanization in developing countries. Whether it was substituting the scythe for the sickle or the co-operative use of farm tractors and other equipment, his work led to increased development in the use of farm equipment overseas.

Cornelius Davies felt that agricultural engineering must have a basis of engineering science, but that the farm mechanization specialist was essentially an agriculturist with a specialized training in modern mechanization. When the Examination Board was first established Dr Davies' services were of special value as he had revised the teaching of agricultural engineering at Wye College and his views were particularly helpful to the Board during the early years. In recognition of his outstanding services to agricultural engineering and to the Institution he was elected an Honorary Member.

"Cornie" as he was known to his friends—and they were many—was a kindly soul with a charming personality. He was also a loyal colleague. His passing will be greatly regretted by all those connected with the Institution and especially by his old friends who took office when the Institution was first founded.

Discussion of papers presented at The Spring National Open Meeting 1967

MR F. E. ROWLAND (Past President, I AGR E) paid tribute to the philosophy underlying Professor Bunting's Paper. He fully agreed that agricultural engineering, particularly overseas, was involved with civil, mechanical, electrical, chemical and other aspects and must not be regarded as only an extension of mechanical engineering as some people in this country mistakenly thought it to be. Turning to the Professor's comments on education and to the communication of information to farmers whose knowledge was rudimentary he referred to the enterprise of two of his friends, settlers in Kenya, who had launched the Narosurra Farm Mechanization Training Scheme. This comprised 12-week courses and the ultimate target was 100 students per course. The fundamentals of the course were both technical instruction and the development of integrity, initiative and character. After 11 months the first batch of 14 students was now tilling 700 acres. One of the problems in developing countries was to inculcate the need for greater production rather than mere subsistence farming. It was therefore encouraging that one of these students had said at the end of the course how essential they realized it to be to increase food production rapidly, not only to feed their own families but also the whole world. In conclusion Mr Rowland reminded young agricultural engineers present of the opportunities to be of service overseas in schemes of this type before settling down to a career.

CAPTAIN E. N. GRIFFITH (Rotary Hoes Ltd) referring to the use of ox-drawn implements commented that the photographs had shown the ox drawing from the shoulders. In order to achieve the most efficient angle of pull in the case of a wheel, pulling must be in a line parallel to the ground and the centre of the axles; pulling from a point higher than this tended to raise the cart or implement up, with a resulting waste of power, and pulling from a lower point drew the attachment into the ground. In the case of the ox, maximum pull was achieved not from the shoulder but from the head, and he believed that the ox once used in China and Italy was always yoked from the forehead. On another point, he said that his Company had been concerned for 20 years with rice production, especially in the East, and from their original work 20 million small machines were developed in Japan. But time was the great difficulty in view of the impending population explosion, and he did not believe that the hand-controlled machine, however excellent its development, could combat the fundamental difficulty of time. The only solution, particularly with wet rice, was the replacement of the numerous small areas with large-scale cultivation, where immediate mechanization was feasible, using tractors and rotary cultivating machines which did not require traction from the tractor. In most non-sticky soils the implement remained extremely clean and unclogged with mud.

MR HAWKINS agreed that it was likely that oxen were more efficient pulling from the head than from the shoulders, but said that measurements were needed to support this view. The comfort of the animal was also important, and he disliked the knobbly pieces of wood frequently placed across the forehead of draught animals —softer and lighter padded pieces should be used. Referring to the global urgency of improved methods of crop production, he said that time was often equally important in the growing of a crop; there was often a limited period in which there was sufficient water reaching the soil to balance or exceed the rate of evapo-transpiration, and it was vital to start the crop at the beginning of this period, not halfway through it. Time limits for planting crops therefore necessitated the change from the small-scale, slow hand method at least to animal-drawn equipment and possibly to the full-sized tractor. A decision on the system to be employed must be taken very early on in mechanization.

MR A. B. LEES (Massey-Ferguson Ltd) said that no animal whether yoked from head or shoulders, was likely to be happy working. The sore shoulders he had observed in the case of animals, and the painful hands and back he had personally experienced, had confirmed him in the belief that plans for better hand and animal tools were a waste of the time of agricultural engineers. Much time had already been devoted to the improvement of agricultural methods, but little success had been achieved, for the reason that no appliance, machine or power, could be better than the men who managed, controlled and serviced them. The basic problem was not agricultural in nature, and therefore the new approach that was required involved a change in economic structure, which appeared nearly impossible, rather than new agricultural engineering techniques. He then invited Mr Hawkins' views as to why tie-ridging had largely been discontinued in the USA over the past 20 years.

MR HAWKINS replied that there seemed to be two contributory reasons, firstly that the dimensions of the basins had been less than was provided by tie-ridging of the type shown on slides that morning; secondly that the climate variations in the United States were not as extreme as in parts of Africa.

MR J. H. W. WILDER (John Wilder Ltd) said that there were many members of NIAE research and experimental staff who believed that a solution for overseas agriculture lay in the two-wheeled ploughing and cultivating implement decried by Mr Hawkins. The lack of a seat for the operator was admittedly a drawback, but the implement had produced good results in Gambia and certain other places. There was evidence that the standard European tractor was now too sophisticated and the simpler Eastern European tractor was beginning to gain increasing popularity even in the United Kingdom. He did not believe that hydraulics and the other accompanying sophistications of the European tractor were really necessary. He suggested that the potential of the 3-wheeled tractor investigated by the NIAE was large, and that the problem associated with this tractor was one of scale of production and method of distribution rather than of its capacity.

MR N. M. GARRARD (NIAE) stated that the Institute had taken part in a project of developing a simple device to aid, in the main, African farmers. The objective was the creation of a multi-purpose tool, so that the farmer would at least have a bullock cart on to which he could attach all the necessary cultivation implements. He had recently studied a draft report from Gambia which attributed to the introduction of this animal-drawn equipment the increase of the peanut crop over the past two years from 118,000 to 132,000 tons. The report showed that very little extra land had been opened up and that it was the cultivation methods and techniques of the system provided by the tool which had resulted in the increased production. This was an outstanding example of success with animal-drawn equipment and there had not been the expensive outlay which sophisticated machinery would have incurred.

MR D. V. CHAMBERS (Hunting Technical Services Ltd) said that whilst there might be a case for the single-axle tractor under certain special conditions, he could not foresee that in peasant agricultural conditions or even conditions of emergent farmers the single-axle tractor would in fact have an important role to play. According to the graph of cost per horsepower supplied by Mr Hawkins, the single-axle tractor was of the order of £40 per horsepower compared to £15 or £16 in the case of the conventional tractor of approximately 60 horsepower. Emergent countries were generally short of foreign exchange, and the single-axle tractor appeared a very bad bargain indeed. Apart from economic considerations, the single-axle tractor when in extensive use in Uganda had not stood up to operation by peasant farmers and a maintenance problem had resulted.

PROFESSOR BUNTING accepted these criticisms of the single-wheel tractor. Nevertheless, the remarkable agricultural revolution in Japan, as demonstrated by the figures given in FAO records, had been achieved with what were termed garden tractors in the FAO statistics, which he believed to be a type of single-axle tractor. 2,000,000 of these tractors were recorded, compared with only a few hundred conventional agricultural tractors, and they apparently worked 6,000,000 acres in a country with a great deal of diversity apart from the vast areas of riceland. Clearly these tractors played a most important part in the remarkable achievement of feeding a more or less stable population of 100,000,000 on a total acreage similar to that of Great Britain, where less than one half of what was eaten was home-produced. The Japanese success might well be applicable elsewhere in the world. Animal-drawn equipment would be less suitable than small machinery in Japan, because the animals would be in competition with humans for food. With regard to the feasibility of the introduction of sophisticated machinery in developing countries, he had frequently been surprised by the speed with which Africans in several different countries had become proficient tractor drivers. Maintenance however was a more difficult problem. It was important that farm workers should be trained to maintain machinery systematically according to a set schedule. One could not expect people without any technical background or education to become competent immediately to maintain machinery; adequate training could help a great deal. A government or a foreign aid agency might spend millions of pounds on the importation of fairly sophisticated machinery to a developing country, and even arrange for the supply of spare parts, but basic training in operation and maintenance was too often neglected. The resulting breakdowns were hardly surprising. If the sophisticated tractor was the correct machine to use from the engineer's point of view, and not merely in the sales director's opinion, then the means of training must be found. The 'package deal' must include (a) the correct technical specification, (b) attention to economic aspects and (c) provision for training.

MR J. A. PATTERSON (New Holland Division Sperry Rand Ltd) paid tribute to Professor Bunting's work in Sudan, which he said was instrumental in the decision to build the Rosares dam. He hoped the Professor had not been discouraged by the closing down of some of the large governmental schemes in that country, because these schemes had been readily taken over by enterprising businessmen, who calculated that they would clear the cost of the equipment in the first year. He then asked Mr Hawkins to comment on the harvesting of crops grown on tied-ridges, and, in particular, on the construction of wheel and tyre equipment required.

MR HAWKINS replied that in the normal course of events the ridge-ties were broken with tines ahead of the tractor wheels. If one considered the crops for which this type of system might be used, and the countries in which it might be applied, it was not possible to think in terms of harvesters at the present time. The fact that it was necessary to harvest from an awkward surface was not sufficient reason for rejecting the system, which he felt possessed advantages in soil and water conservation that outweighed harvesting difficulties.

MR LANKESTER (Unilever Plantations Group) said that his experience in tropical countries bore out the need for simplicity in the design of machinery, to reduce the trail of broken-down machinery so frequently visible; with simplicity must be linked efficient after-sales service.

Another speaker said that Mr Hawkins had demonstrated the advantages of using draught animals as the motive power for agricultural mechanization. In the arid and semi-arid regions of the world, however, there were distinct disadvantages in attempting to integrate any form of livestock into an arable cultivation system. The animals would require food and water all year round, and the economics of making such provision might well be daunting. Moreover in those countries where animals were in current use as a form of power, general-purpose animals were the norm which provided meat and milk as well as horsepower. There was as yet no equivalent of the English farm horse in any of the under-developed countries, and an animal which was expected to fulfil a variety of requirements was unlikely to be highly efficient in meeting any one of them. For these reasons he believed that animals had little potential as a means of mechanization.

PROFESSOR BUNTING replied that many observers of ox-ploughing in countries such as Zambia seemed to have been very impressed by what had been achieved. He considered that the problem should be approached as a joint animal husbandry and agricultural engineering exercise. There were many reasons why the reported successes would not have been expected (including disease), and it was particularly surprising that the animals were able to do their heaviest work at a time of year when shortages of food and water were most acute. The real necessity, however, was for the collection and assessment of facts on the feeding, health and work output of the animals.

MR F. COLEMAN (Consultant) offered comments on animal/implement relationships. He agreed with Mr Hawkins that the implement should be as simple as possible, but said it was important first to examine the indigenous implements whose size was normally related to the type of materials locally available. Draught could be reduced by reducing the size of the scratch-plough bodies. He was convinced that the long pole was a great help in reducing angles of attack to the soil, and had the advantage of being much simpler than any form of chain harness. Some 15 years ago FAO had experimented in Egypt with Swiss harnesses for bulls, but without any real success. The difficulty in the case of bulls and buffaloes lay in their anatomy, which did not easily allow collars without the restriction of their air supply. This was a veterinary and agricultural engineering problem.

MR HAWKINS said that he had not advocated collars as such. He had intended to stress that the indigenous implements were frequently capable of improvement by the sort of work currently being carried out in the United Kingdom. Whether the harness was based on the long or short beam, it was in either case susceptible to improvement beyond the straight crude, often knobbly, wooden member. More information was certainly needed for the right design of harness for these various animals.

ELECTIONS AND TRANSFERS

Approved by Council at its meeting 6 April 1967

ADMISSIONS

Associate Member

Overseas	Herath, K.	Ceylon
	Jack, J.	Lancs
	Muckle, T. B.	Salop
Overseas	Rafi, M.	West Pakistan
	Rice, B. G.	Eire
Overseas	Rodger, K.	Denmark
	Savage, W. L.	Lincs
	Webb, S. C.	Yorks

Associate

	Birchenhough, A.	Dorset
	Bonner, R. H.	Kent
Overseas	Brumwell, C. J.	Canada
	Clover, C. H.	Lincs
	Duncan, I. J.	Surrey
	Edwards, J. M.	Warwicks
	Goodfellow, K. A.	Lincoln
	Hall, D. A.	Peterborough
	Harris, A. G.	Salop
Overseas	Harrod, E. J.	Rhodesia
Overseas	Holmes, H. W.	Australia
	Jeffes, R. H. F.	Glos
	Knight, R. J.	Bristol
Overseas	Oliver, G. J.	Rhodesia
	Simpson, C. C.	Suffolk
	Wilkinson, D. W.	Yorks
	Woodward, D.	Scotland

Graduate

	Beaty, J. D.	Staffs
	Burr, I. R.	Scotland
	Blackwell, J.	Berks
	Cutler, F.	Warwicks
	Disney, R. E. L.	Hants
	Duff, J. W.	N. Ireland
	Foulger, S. R.	Dorset
	Frost, A. C.	Essex
	Morris, J. L.	Salop
Overseas	Ngei, O. O.	Nigeria
	Nutt, G. T.	Berks
	Prout, K. J. F.	Essex
	Shapland, A. H. T. F.	Kent
	Shaw, J. A.	Yorks
	Shepherd, H. M.	Scotland
	Stephens, E. G.	Worcs

ELECTIONS AND TRANSFERS *(continued)*

Approved by Council at its meeting on 6 April 1967

Student	.. .. ..	Bomford, C. A.	Berks
	.. .. ..	Davis, R. A.	Beds
	.. .. ..	Ford, W. R.	Wilts
	.. .. ..	Fynn, R. P.	Dorset
	.. .. ..	Hollick, M. F. G.	Surrey
	.. .. ..	Jackson, T. R.	Beds
	.. .. ..	Judson, C. A.	Beds
	.. .. ..	Mander, C. E.	Birmingham
	.. .. ..	McCracken, A.	Essex
	.. . ..	Osborne, R. C.	London
	.. .. ..	Packard, J. W.	Wilts
	.. . ..	Shaw, R. I.	Essex
	.. .. ..	Walton, J. A.	Beds
	.. .. ..	White, I. S.	Beds
	.. .. ..	Williams, J. R.	Essex

TRANSFERS

Member	.. .. ..	Gregory, T. P. ..	Hants
	.. .. ..	Inns, F. M.	Beds
	.. .. ..	Whitaker, J. R.	Yorks
Associate Member	.. .. ..	Barton, P. S.	Sussex
	.. .. ..	Catt, W. R.	Wilts
	.. .. ..	Cowan, R.	Newcastle-upon-Tyne
	.. .. ..	McGrouther, J. B.	Scotland
	.. .. ..	Pollock, J. R...	Scotland
	.. .. ..	Sartain, J. C...	Wilts
	Overseas ..	Weaving, T. F.	Libya
	.. .. ..	Webb, D. G...	Sussex
Associate	.. .. ..	Brettell, P. W. M.	Lincs
	.. .. ..	Litton, R. H.	Dorset
	.. .. ..	Roberts, J. W.	Yorks
	.. .. ..	Salmon, F. G.	Oxon
	.. .. ..	Webb, T.	Somerset
Graduate	.. .. ..	Charlton, B.	Hants
	.. .. ..	Darcel, C. J.	Hants
	.. .. ..	Halford, D. G.	Lancs
	.. .. ..	Hay, R. C.	Warwicks
	.. .. ..	Lewis, T. G.	Sussex
	.. .. ..	Martin, M. S.	Hants
	.. .. ..	Morrish, D. E.	Hants
	.. .. ..	Waterson, R. J.	Bucks
	.. .. ..	Webb, B. T.	Bucks

BRANCH HONORARY SECRETARIES

EAST ANGLIAN

J. B. MOTT, AMI AGR E
County Education Offices
Stracey Road, Norwich, Norfolk

EAST MIDLANDS

R. D. S. BARBER, BSC, ND AGR E, AMI AGR E
The Farm Institute
Caythorpe Court, Nr Grantham, Lincs

NORTHERN

D. J. GREIG, BSC, MSC(AGRIC ENG), AMI AGR E
Dept of Agricultural Engineering
University of Newcastle
Newcastle-upon-Tyne 1

SCOTTISH

A. HARDIE, BSC, AMI AGR E
Edinburgh School of Agriculture
West Main Road
Edinburgh 9

SOUTH EAST MIDLANDS

G. SPOOR, BSC(AGRIC), MSC(AGRIC ENG), GRI AGR E
National College of Agricultural Engineering
Silsoe, Beds

SOUTH WESTERN

J. M. HAMPSHIRE, AMI AGR E
Fasano, 41 Countess Wear Road
Exeter, Devon

WESTERN

H. CATLING, ND AGR E, AM I AGR E
Engineering Dept
Royal Agric. College, Cirencester, Glos

WEST MIDLANDS

D. H. ROWE, AI AGR E
Hines House, Banbury Road
Stratford-on-Avon, Warwicks

YORKSHIRE

T. H. E. HARRISON, BSC(AGRIC), MSC(AGRIC ENG) AMI AGR E
3 Foxglove Road, Almondbury
Huddersfield, Yorks

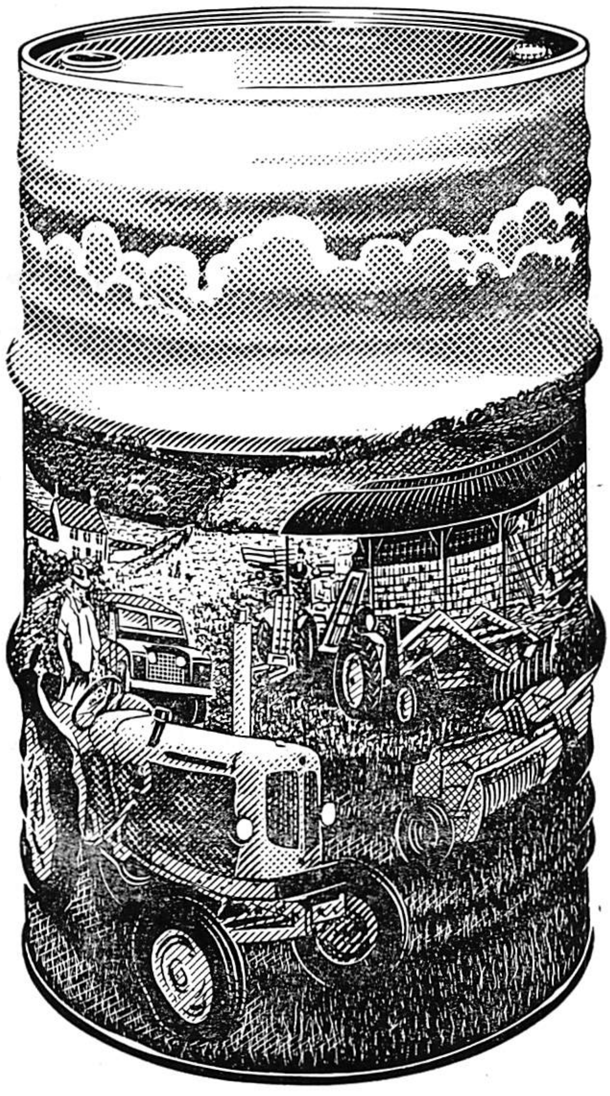
Index to Advertisers

Abbreviations and Symbols used in the Journal

a	year
A or amp	ampere
ac	acre
a.c.	alternating current
atm	atmosphere
b.h.p.	brake horse-power
bu	bushel
Btu	British Thermal Unit
cal	calorie
c.g.	centre of gravity
C.G.S.	centimetre gramme second
cm	centimetre
c/s	cycles per second
cwt	hundredweight
d	day
dB	decibel
D.B.	drawbar
d.c.	direct current
°C, °F, °R	degree Celsius, Fahrenheit, Rankine
deg	degree (temperature interval)
dia	diameter
doz	dozen
e.m.f.	electromotive force
ft	foot
ft^2	square foot (similarly for centimetre etc.)
ft lb	foot-pound
G.	gauge
g	gramme
gal	gallon
gr	grain
h	hour
ha	hectare
Hg	mercury (pressure)
hp	horse-power
h	hour
in.	inch
in^2	square inch
i.d.	inside diameter
kWh	kilowatt hour

l	litre
lb	pound
lm	lumen
m	metre
max.	maximum (adjective)
m.c.	moisture content
m.e.p.	mean effective pressure
mile/h	miles per hour
mill.	million
min	minute
min.	minimum (adjective)
o.d.	outside diameter
o.h.v.	overhead valve
oz	ounce
Ω	ohm
pt	pint
p.t.o.	power take-off
qt	quart
r	röntgen
r.h.	relative humidity
rev	revolutions
s	second
s.v.	side valve
S.W.G.	standard wire gauge
t	ton
V	volt
v.m.d.	volume mean diameter
W	watt
W.G.	water gauge
wt	weight
yd	yard
$>$	greater than
$\ngtr$	not greater than
$<$	less than
$\nless$	not less than
$\propto$	proportional to
$\sim$	of the order of
° ′ ″	degree, minute, second (of angles)

The above abbreviations and symbols are based mainly on B.S. 1991 (Part 1), 1954



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