Journal and Proceedings of the Institution of Agricultural Engineers

SPRING
and
SUMMER
1968

Vol. 23 No. 3

THE NATIONAL COLLEGE OF AGRICULTURAL ENGINEERING, SILSOE, BEDFORD

Scene of the Institution's very successful Symposium held there in 1967, the National College of Agricultural Engineering at Silsoe is to be the venue for the Institution's Spring National Meeting 1969, with the theme 'Planning and Executing the Development of Agricultural Resources'. The meeting is being arranged for Thursday, 27 March, next year, and will be the second in the series entitled 'The Contribution of Agricultural Engineering in Developing Countries.

The College, founded by Trust Deed in 1960 and sponsored by the Secretary of State for Education and Science, stands in 32 acres of attractive grounds near the village of Silsoe, about 40 miles north of London and 10 miles from the county town of Bedford. It has as its primary object the provision of coherent and systematic engineering training appropriate to the varied needs of world agriculture. (Picture by courtesy of 'The Times'.)

JOURNAL AND PROCEEDINGS OF THE INSTITUTION OF AGRICULTURAL ENGINEERS

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INSTITUTION NOTES

An Institution for the 'Seventies

In its Annual Report for 1967, Council mentioned that the need had arisen to study more closely the future status of the agricultural engineer within the context of the Council of Engineering Institutions. A Constitutional Working Party, comprised of senior officers of the Institution, has been engaged on this challenging task; discussions with kindred institutions and other bodies have taken place. Council is convinced that some form of association with CEI, short of actual constituent membership, would be of great benefit.

Meanwhile, plans are well advanced for re-designing the structure of the Institution so that its relevance within the entire engineering spectrum can be more easily discerned, whilst still retaining its own identity and rationale for the agricultural engineering community. Council has recognized the primary need to distinguish between the two types of engineer currently falling within the definitions originated by The Engineering Societies of Western Europe and the USA (EUSEC).

These definitions have been adopted in turn, with slight amendments, by CEI and its Constituent Institutions, and by many other institutions outside CEI, to interpret their membership requirements. Council believes this calls for an acceptance of the differentiation between the degree-level agricultural engineer and the diploma-level agricultural engineer within the Institution's future membership structure. Both types of engineer have co-existed for many years in the Institution's corporate membership and it is fully intended that they should continue to do so. The re-designed structure will offer a new corporate grade of Fellow to agricultural engineers aged not less than 35 years and who have qualifications equivalent to those of Chartered Engineers, while the existing corporate grade of Member will continue to accommodate diploma-level agricultural engineers qualified to the Institution's current requirements for the grade of Associate Member. In this process of rationalization, it is intended to lower the normal minimum age of entry to the grade of Member from 40 to 25, and to discontinue the grade of Associate Member entirely.

As a mechanism for giving effect to these important changes, it is planned to re-designate all Members as Fellows and all Associate Members as Members, respectively, on 1 January 1969. By this means, the Institution's existing corporate membership will be fully safeguarded and the Institution would expect, through members' continued allegiance, to foster the high standards that the new membership regulations will require from the agricultural engineering profession in the 1970's.

Although the new membership structure is the main highlight of the new constitution, other changes to be suggested include an increased representation of corporate members on the Council, greater flexibility in the administration of examinations undertaken by the Examination Board, and amendments to the Institution's Memorandum which will assist the Institution to be registered as a Charity under the Charities Act 1960.

Extraordinary General Meeting

Members are asked to note that an Extraordinary General Meeting of the Institution will be held at the University of Reading, Palmer Building, on Thursday 26 September 1968 at 1630 hours. Its purpose will be to seek approval for changes in the Memorandum and Articles of Association of the Institution, together with new scales of annual subscriptions and fees, to take effect from 1 January 1969. Full details will reach all members during the summer.

I Mech E and I Agr E Joint Working Party

Prompted by the need for closer collaboration, the Institutions of Mechanical Engineers and Agricultural Engineers are to set up a Joint Working Party to discuss matters of common interest. These will include the promotion of agricultural engineering in the context of the engineering profession as a whole. There is no intention of amalgamating the Institutions.

The Joint Working Party will also discuss the best way of supporting plans for establishing the award of a National Title for Technician Engineers including the qualification standard with which that title should be associated. In addition, it will look at other matters in which collaboration is practical, such as the possibility of the two Institutions sharing certain administrative facilities in order to reduce costs.

The Institution of Mechanical Engineers with a membership of 69,000 has recognized the contribution of the 2,000-strong Institution of Agricultural Engineers in the field of agricultural engineering. Although discussion and co-operation between the two Institutions have gone on for many years on an informal basis and the Institution of Mechanical Engineers have always welcomed meetings with the Institution of Agricultural Engineers, this is the first time that informal discussions on mutual co-operation have taken place.

Continued on next page

Annual General Meeting and Presidential Address 1968

The twenty-third Annual General Meeting of the Institution was held on the premises of the Institution of Mechanical Engineers in London on 9 May. The Annual Report of the Council was presented to the meeting by the President, Mr T. Sherwen. He stressed the great importance of the need for a useful and friendly association with the Council of Engineering Institutions. Mr Sherwen also reported that the Institution had participated in discussions concerning a national title and qualification for technician engineers in industry. He said Council had already adopted as its guiding principle that parity must be clearly seen to exist between the minimum standard of entry to the new Membership grade in 1969, and whatever nationally recognized qualification and status was eventually devised to apply to diploma-level engineers. After paying tribute to the work of the Examination Board, Standing Committees and Branch Committees for their untiring efforts during the year he thanked his fellow Council Members and the staff for the assistance and support he had personally received from them.

The accounts for the year were presented by the Honorary Treasurer, Mr E. Atkinson. Drawing attention to the inescapable excess of expenditure over income, he said that plans had been completed for improving the capital situation by means of the 30-Year Anniversary Endowment Fund and, further, an advanced stage had been reached in drafting new scales of annual subscriptions and fees to be introduced in 1969 concurrently with the new membership regulations. The accounts were adopted. The existing auditors were appointed for a further year.

The President, Past Presidents on Council, Vice-Presidents and Council Members eligible for re-election were duly appointed to hold office for a further year. In addition, the following Officers and Council Members were appointed to fill vacancies arising on the Council:

President Elect

H. C. G. Henniker-Wright, mi agr e—Ford Motor Company Ltd

Vice-President

A. C. Williams, mi agr e—'Farm Mechanization & Buildings'

Ordinary Members of Council

B. Burgess, dip agric, mi agr e—Ben Burgess Tractors Ltd

J. R. O'Callaghan, phd, m sc, mi agr e—University of Newcastle-upon-Tyne

T. W. M. Cook, ami agr e—William Cook Engineers Ltd

M. Searle, ai agr e—Agricultural Machinery and Tractor Dealers Association Ltd

A. W. B. Davies, nd agr e, gri agr e—East Riding College of Agriculture

After the conclusion of the A.G.M., Mr Sherwen presented his Presidential Address entitled, 'The Role of the Inventor in Engineering'. This is reproduced in full elsewhere in this issue of the *Journal.*

30-Year Anniversary Endowment Fund

During the course of the Annual General Meeting referred to above, the President put forward a strong appeal for more support for the 30-Year Anniversary Endowment Fund, as reported on page 90 of this *Journal.* Although many members have responded promptly and generously to the appeal, it has a long way to go and is far short of the anticipated target of £10,000. The closing date is not until 30 March 1969, but it is earnestly hoped that every member who has not yet responded to this appeal will do so without delay. A brochure giving full details of the aims and objects of the fund reached every member throughout the world some weeks ago; additional copies can be obtained on application to the Secretary.

Members attached to a branch of the Institution are urged to make contact with the Branch Honorary Secretary to whom donations can be handed, or they can be sent direct to the Institution Secretary at Rickmansworth, using the donation slip appearing at the foot of the opposite page, whichever is preferred. Cheques should be made payable to 'The Institution of Agricultural Engineers'. All donations will be individually acknowledged and receipted.

Please turn to page 83

30 YEAR ANNIVERSARY ENDOWMENT FUND

HELP!

It is hoped that members everywhere might feel able to donate a sum approximating to their annual subscription. The corresponding capital sum would be approximately £10,000. With it your Council would have no more available than that enjoyed by Institutions of comparable size which, perhaps, may not have such a stimulating future. Furthermore, the Council would, where necessary, be able to have greater influence in furthering the interests of members and would have some flexibility in considering additional activities which would be beneficial to the Institution.

How?

You may send your cheque, postal order or money order together with the attached form direct to the Secretary of the Institution or, if you are a branch member, you may wait until the fund-raiser appointed by your branch Chairman gets in contact with you. Your contribution to the fund may be sent together with your annual subscription in the same cheque.

What?

If you are in doubt how much you should contribute, discuss it with your local fund-raiser, or if you are not in a branch or live overseas the Secretary of the Institution will be pleased to help you. If each member donated a sum equivalent to his annual subscription, we could raise £10,000.

.... **CUT HERE** ....

To: **The Institution of Agricultural Engineers**
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I attach cheque/money order/postal order as my donation to the 30-year Anniversary Endowment Fund of the Institution.

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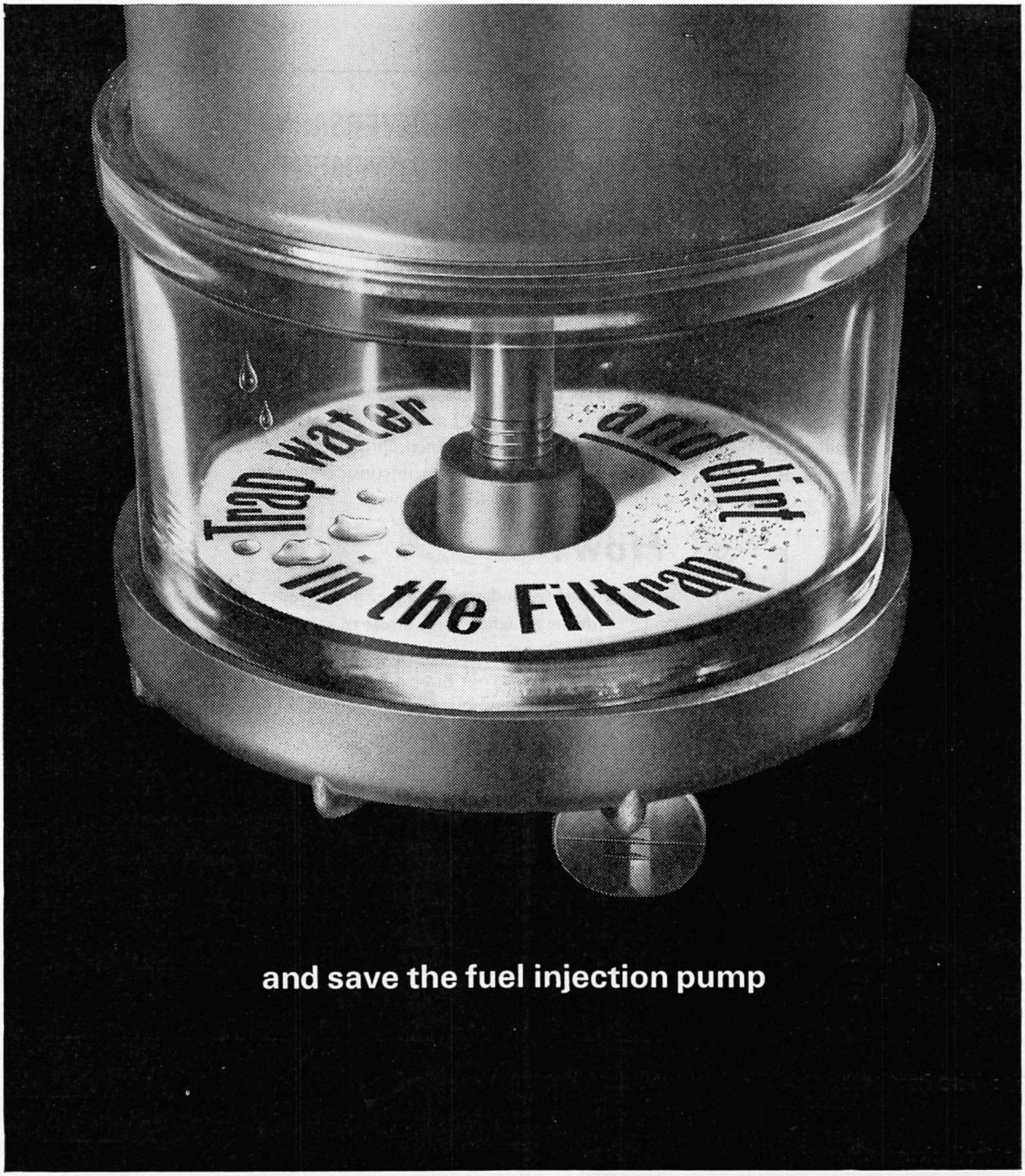

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The Future of the ND Agr E

The Examination Board in Agricultural Engineering announces that, in view of the establishment of a new pattern of courses under the Joint Committee for National Awards in Agricultural Subjects, which, in consultation with the Engineering Joint Committee, will make provision for examinations in Agricultural Engineering and Mechanization, the National Diploma in Agricultural Engineering (ND AGR E) will in due course cease to be offered.

Provided that new courses and examinations offer acceptable alternatives of a suitable standard for candidates to whom the ND AGR E is now available, the Board will expect to hold the last full examination for the National Diploma in Agricultural Engineering *not earlier* than in 1972. Arrangements will be made for resit examinations either in 1973 or perhaps later in 1972, for candidates who fail in that year.

In making this announcement of eventual withdrawal of the National Diploma, which the Board introduced in 1951 as a pioneer qualification in Agricultural Engineering at diploma level, the Board notes the part which has been played by the Department of Education and Science in developing facilities for courses in Agricultural Engineering and Mechanization, and acknowledges that it will soon be appropriate to hand over to the Department full responsibility for the National aspect of the Board's examination work.

Qualification at ND AGR E level will continue to be the minimum technical standard required of future applicants for corporate membership of the Institution of Agricultural Engineers. The Institution will determine the acceptability for this purpose of the new examinations which are to be introduced.

An early opportunity will be taken of reviewing the future of the Institution Part II Examination in the light of the developing pattern of qualifications in agricultural engineering subjects.

New Qualifying Standards

Later this year, a completely revised Membership Guide will be published, listing the precise academic and other requirements applicable to Graduate and corporate membership with effect from January 1969 until further notice. The non-corporate grade of Associate is designed to continue much as at present but will be broadened in scope to permit the admission of virtually any person over 21 years of age who has a genuine interest in agricultural engineering.

Examination standards involved in progression to corporate membership will be at four levels; the relationship of these four levels of attainment, Part I, IIA, IIB and III, to the requirements for admission to the grades of Graduate, Member and Fellow, are to be as follows:

Age	*Technical Qualifications required in addition to Part I from January 1969 to December 1973*		
	Graduate	*Member*	*Fellow*
Under 30	Part II (A or B)	Part IIA	(not applicable)
30–35	Part II (A or B)	Part IIA or Part III	Part IIB (specially approved candidates only)
Over 35	Part II (A or B)	Part IIA or Part III	Part IIB or Part III
Over 40	(not normally applicable)	Part IIA or Part III	Part IIB or Part III

Academic qualifications satisfying the requirements of Part I will continue as at present. The Part IIA level will be similar to the present Part II requirements. Lists of currently acceptable Parts I and II qualifications can be found in the 1968 *Yearbook*.

THE INSTITUTION OF AGRICULTURAL ENGINEERS

AUTUMN OPEN MEETING

The Institution is to hold an Open Meeting on

SYSTEMS ENGINEERING in AGRICULTURE

on THURSDAY, 26 SEPTEMBER 1968, at READING UNIVERSITY

The full programme for the day will be as follows:

10.00 Assembly: Coffee

10.30 **Paper I:** 'An Outline of Systems Engineering' (to describe the development of systems engineering as a method of approach to complex problems of design, selection, distribution or management and to outline some of the important techniques now available)

Author: PROFESSOR J. F. COALES (Professor of Control Engineering, Cambridge University)

Chairman: Professor Fellgett (Professor of Cybernetics and Instrument Physics, Reading University)

11.30 **Paper II:** 'A Systems Approach to Farm Machinery Selection' (to describe methods of qualifying machine performance and of developing a computer programme for selecting systems of mechanization)

Author: DR DONNELL R. HUNT (Professor of Agricultural Engineering, University of Illinois, U.S.A.)

Chairman: Mr J. A. C. Gibb (Senior Lecturer in Agricultural Engineering, Reading University)

12.30 Luncheon

13.45 **Paper III:** 'The Systems Approach to Engineering Design' (to discuss applications of systems engineering to problems of design)

Author: PROFESSOR J. R. O'CALLAGHAN (Professor of Agricultural Engineering, University of Newcastle)

Chairman: Professor P. D. Dunn (Professor of Engineering Science and Head of Department of Applied Physical Sciences, Reading University)

14.45 **Forum:** To discuss applications of systems engineering in agriculture.

16.00 Tea

16.30 Open afternoon at the Applied Physical Sciences Department and computer demonstrations in the Computer Unit (concurrent)

16.30 Extraordinary General Meeting of the Institution (*for members of I Agr E only*)

TICKETS: Members (other than Student Members) 25/-; Student Members 15/-; Non-Members 30/-. The charges include advance copies of full texts or synopses of papers (depending on availability), morning coffee, luncheon and afternoon tea as well as admission to the morning and afternoon sessions of the meeting. *Early application for tickets is very strongly advised.*

The following are examples of minimum qualifications at the new level of Part IIB for the grade of Fellow, from 1 January 1969:

Parts I and II of the CEI Examination (subject to I Agr E stipulating options under Part II *or* subject to the candidate having been a practising agricultural engineer for a period of not less than two consecutive years);
Associateship of the National College of Agricultural Engineering;
BSC from the National College of Agricultural Engineering;
BSC(AGR ENG) from Universities in U.K. and Eire;
M AGR SC (Farm Mechanization) or (Agricultural Buildings) from the University of Reading;
MSC(AGR ENG) or (AGR BUILDINGS) from the University of Reading;
MSC(AGR MECH) or (AGR ENG) from the Universities of Dunelm or Newcastle;
Post-graduate certification in appropriate subjects at NCAE, based on underlying degree-level qualification;
At the discretion of the Council, *and* provided the candidate is a practising professional agricultural engineer and has been so for a period of not less than two consecutive years, any of the following:
(a) C Eng via corporate membership of any CEI Constituent Institution;
(b) Approved degrees in engineering or a relevant technology from overseas universities.

Winter Session 1968/69

Under the aegis of the Council and its Papers Committee, together with the nine Branch Committees throughout the United Kingdom, plans are now very well advanced for the nation-wide programme of meetings, conferences, technical visits and social occasions for the next winter season. A pocket booklet will reach every member during the Autumn giving outline details of these activities. This will be followed up during the Winter by individual notices and reminders about particular events of interest to members in their own Branch area.
Full details will be found on the page facing these notes of the Autumn National Meeting of the Institution to be held at the University of Reading on 26 September 1968. In March 1969 the Spring National Open Meeting will be held at the National College of Agricultural Engineering, Silsoe, when a series of papers will be presented on the theme of 'Planning and Executing the Development of Agricultural Resources'. Brief details of this event will be found on page 90 of this issue of the *Journal*. To complete the programme of national activities, the Institution's Annual Conference, Annual General Meeting and Annual Dinner will be held in London on 8 May 1969. The subject theme for the Conference will be 'The Mechanization of Spaced Row Crops', further details of which will be announced as soon as possible.
Once again, members everywhere are asked to support the Institution's activities, particularly in Branch Areas. Not only are these meetings of great benefit in themselves, but they also provide a medium of introducing potential members of the Institution; no opportunity should be lost of bringing guests to these activities and introducing them to the Branch Honorary Secretary where a genuine interest in membership of the Institution has been displayed.

Publications

Regular readers of the *Journal* will have noticed that this issue is larger than usual. This is because it has regretfully proved necessary to publish issues less frequently during the past year owing to staff shortage, re-scheduling of published material as a consequence of the Symposium being held last September, and a severe budget in the present economic circumstances. Members may like to note that Volume 23 Part IV will be issued in the Winter and thereafter it is the intention to revert to the normal quarterly cycle of publication, commencing in Spring 1969. Members can be assured that by then the entire backlog of material awaiting publication will be in their hands. Publication of the *Yearbook 1968* has also suffered delay but this should be delivered at about the same time as this issue of the *Journal*. Future issues of this annual publication will be circulated in the Autumn of 1969 and subsequent years.
Production of the Proceedings of the 1967 Agricultural Engineering Symposium are at an advanced stage. Fully illustrated and indexed versions of the 49 papers together with supporting discussions will comprise the invaluable contents of this publication which will be supplied automatically in an attractive binding to all those who attended the Symposium on full registration. The Proceedings will be available on sale, complete with binder, at a cost of £9 per volume, post free. Individual papers will also be available, unbound, at a cost of 7/6 per copy, post free.

THE PRESIDENTIAL ADDRESS 1968

THE ROLE OF THE INVENTOR IN ENGINEERING

by

T. SHERWEN, C ENG, MI MECH E, MSAE, MI AGR E, *President of the Institution*

Presented prior to the Annual Conference of the Institution in London on 9 May 1968

The part played by the inventor has always been controversial in all forms of development, especially those involving engineering disciplines. His very name is frequently preceded by the adjective 'mad' because his thoughts and outlook on affairs are often so far removed from those of ordinary folk. However, the part he plays is more important than ever today when all industries are being exhorted to even greater efforts in the export field.

First, we must attempt to define an inventor and this is no easy task, since there are so many variations. Basically, an inventor must be capable of original thought and must be able to crystallize the requirements of a particular problem and from these arrive at a specification, which must be satisfied before a solution is possible.

Let us examine for a moment some of the ways an inventor works, Very seldom does he leap out of his bath shouting '*Eureka*'. The flash of inspiration, although it does happen sometimes, is very rare, and an invention is more likely to be the result of some hard and well regulated thinking. It is often possible to form a mental image of the requirements with eyes closed and then various solutions can be selected from the memory's stock and offered up to see if they will fit.

It is very difficult to describe this process in words because so many factors have to be taken into account but the mind allows for these much as a computer would, and breadth of experience provides a larger stock of ideas from which to select the right one.

A physiological peculiarity which exists is the fact that often the first solution to a difficult problem is by far the hardest. Once one has the first solution it seems to be much easier to think up a second and third and then one can evaluate the pros and cons of the alternatives and decide which will be the best answer. Sometimes the first answer to a problem looks as if it is going to be too complex. However it is worth proceeding with because it is usually easier to simplify a solution than to arrive at the final version with first thoughts. These are generalizations but have been found by experience to apply to the solving of many different problems.

I seem to be trying to prove how humdrum the process of invention is but of course this is not so. Ideas need the right environment before they can flow and can rarely be made to appear to order during office hours. This leads to many of the social problems experienced by inventors because while a problem is being solved the inventor is not good company and does not appear to listen when spoken to.

I have referred to the inventor as being male. Really there is no reason why this should be so but the fact remains that most creative designs seems to stem from men, even when it comes to fashions in women's clothes. Also I can think of no woman composer though many are brilliant performers. Perhaps there are some profound biological reasons why this should be. If so, I have never heard them explained.

The previous definition of an inventor straight away provides the fundamental difference between an inventor and a designer although often one person can be both. The designer starts on an idea which has previously existed and translates it into a layout drawing from which the parts are detailed and made. A man can be an inventor whether he is concerned with children's toys or a new type of bridge. It is the thought processes and abilities that matter. For the same reason inventors are born and not made. This is not to say that training and education do not help; the right circumstances and facilities are most important factors.

The creation of new ideas also needs the right environment in several basic aspects. First, there must be relative quietness. I say relative, because some music can act as a stimulus to certain people. On the other hand a pneumatic drill just outside the building would inhibit most constructive thinking. Next, from the visual aspect, the surroundings should be well lit, with no visual distraction. I should explain that this does not mean there should be no pictures or view but, for instance, a window looking out over a busy river would tend continually to usurp the attention.

Finally, financial circumstances are an important part of the right environment. No inventor can give of his best if he is continually worried about making ends meet. The financial rewards must in fact be adequate to attract the right type of candidate. By the same token, if an inventor comes from a wealthy family and has administrative abilities then he will achieve greater success in life because he can organize the right environment for his inventions to be developed and exploited commercially.

One of the best examples of this type of inventor was Sir Charles Parsons who was born to a wealthy family. The family seat was at Birr Castle in Ireland which had a forge and well-equipped workshops. Here it was that

Charles spent much of his youth learning the basis of engineering practice with his brother, Clere. The result of this background was a man who was not only an advanced 'inventor' but a brilliant practical engineer who, for instance, had to learn and solve many of the problems of cavitation of propellers before he could exploit the full advantage of turbine propulsion in 'Turbina'. At the same time he had the influence and abilities to set up companies like the Parsons Marine Steam Turbine Co. at Wallsend, to manufacture and market his designs. No wonder his reputation as a great inventor will go down to posterity.

Turning to the agricultural field, John Fowler is another excellent example of the same class of inventor. In this case, however, the steam traction engine was already known so that Fowler's efforts consisted mainly in developing the practical use of these for steam ploughing and other operations, and perfecting these systems so that they could show a cost saving over horse ploughing.

These are two examples of inventors who achieved fame largely because they had the opportunities to exploit their inventions. Not many inventors were so fortunate and where they had to work for a company their inventions became companies' property. Seldom was the inventor's name ever associated with it in the public eye. Furthermore, inventive ability is usually only part of a person's character and the combination of this with other attributes decides how far that person will progress in life and how successful he will be.

An inventor's stock-in-trade is a huge store of ideas on methods of construction materials, fastenings, etc. from which he can draw and which he uses as the construction material with which to build up his ideas. For this reason his usefulness will suffer if he is confined too much to an office. He must get out and see how other people solve similar problems, as freqently this will stimulate him into evolving improvements which can give his own company's products a sales lead over competitors.

The eighteenth and nineteenth centuries represented a fruitful period for inventors. There are many reasons for this. For one thing, several lines of development were interdependent. Steam power, for example, altered the whole outlook on many engineering subjects. Two other aspects, however, were even more important. Firstly there were considerable profits to be made from the successful exploitation of new ideas in engineering and the prevailing taxation allowed much more of these to be retained in the business. Furthermore, the industry consisted of a multitude of small firms in contrast to the commercial empires which exist today and, because of this, internal communications and company loyalties were on the whole much higher. In this atmosphere inventiveness was encouraged since it often paid good dividends in a short time. Specialization was uncommon and the pioneer inventors of this period had a breadth of outlook and knowledge which is not often found today.

At this stage I want to enlarge on the previous remarks about environment. This must include facilities and since we are talking about inventors in engineering, this will mean a workshop. Every successful inventor must be able to try ideas out, often in model form and in this way he can prove any doubtful feature of a new idea. Moreover, dealing with new materials that become available, he can discover their suitability for various purposes and generally get a 'feel' for their usefulness.

Returning to the nineteenth century the common prevailing materials were wrought iron, cast iron and timber. These were formed and fabricated up and down the country by hundreds of blacksmiths in every town and village. Many of these included small foundries and this is where most of the inventors of this period started. These establishments were in fact miniature engineering works and it is surprising what some of them could do under an ingenious blacksmith. These conditions provided exactly the right background for the inventor. He could make, say, a new type of implement quite quickly. It could be tested locally (as in most cases only local markets and hence, local conditions, were considered) and a fair profit could be made in manufacture and sale.

In the agricultural industry the early part of the century was the start of a long period of change as far as the inventor was concerned. One could say that items were virtually hand-made then and were not influenced by machine tools as such. Gradually, however, the machine tool industry grew as a result of the demand for more accurate parts, which could not be satisfied by existing casting and forging methods. This trend began to alter the whole character of industry. The more progressive units grew and extended their activities. The change-over from the power of the horse, first to steam power and later to the I.C. engine led to an ever-increasing demand for more load and speed in transmissions. This encouraged, among other things, the development of gear-cutting machines, which illustrates the increase of sophistication of all machining processes.

The progress of mechanical engineering and the activities of the inventor have always been closely interwoven with sources of power and energy, so it is natural that the invention of the internal combustion engine towards the end of the nineteenth century should have a tremendous influence on events.

It was the ideal power source for the aeroplane and the automobile and replaced steam on the tractor. Naturally this was a period of great activity for the inventor since there were good commercial opportunities for those companies who produced and sold progressive engineering products. In fact many of the present great engineering empires were started during this period and their founders were the pioneer engineer/inventors of the day.

The advent of the first World War sustained the demand for the inventor since this was the first war in the world's history where land and air fighting devices had their own power for mobility.

It is a tragic reflection on man's intelligence that his engineering developments over the last 150 years should have been used to increase his destructive power over his fellow men to such an overwhelming extent.

Turning to the twentieth century the biggest single influence on progress in engineering was the invention of the I.C. engine. This made the aeroplane and the motor

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THE PRESIDENTIAL ADDRESS 1968

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car possible and revolutionized the development of the tractor. The role of the inventor in the earlier part of this period was considerable but after the end of the first World War it diminished for several reasons. The first of these was that the basic components of the tractor and the automobile had been invented and were now undergoing a period of refinement and process development which needed a very different type of engineer. Secondly, mass production had been pioneered by Henry Ford and a large portion of development was aimed at easier production rather than at any specific improvement in the component. Also the tremendous capital investment need for mass production inhibited rapid change since a minimum obsolecent period was required to amortize these costs. This led broadly to a situation where fewer inventors were needed, added to which the economic troubles in the early 1930's slowed down expenditure on new thinking and development. One cannot leave this period without mention of Harry Ferguson since he was responsible for the only major step forward in the agricultural engineering industry between the two wars, i.e. the mounting and control of implements on the rear of the tractor. This practice has been adopted almost universally and no medium-sized tractor could now be sold without a three-point linkage. The increase in specific tractor work out-put which resulted from this step has helped food production to an appreciable extent.

The approach of the second World War again created a situation where we needed the inventor if we were to survive the onslaught of Hitler. Anyone who has read the book 'Wheezers and Dodgers' will know the contribution made by inventors to the salvation of Europe, one excellent project example being PLUTO and the best example of the man being Dr Barnes Wallis with his significant contributions to structures and aerodynamics.

After the war labour was very scarce and expensive, and this upset the normal ratio in costs between labour, materials and overheads. Thus, much of the post-war thinking in agricultural engineering was directed to cutting down the labour content in all operations. This led early on to such things as front-end loaders and manure spreaders. However very few of these handling devices were invented over here—most of them came from the U.S.A. and the ideas were modified and adapted to suit U.K. conditions and tractors.

This was the result of the engineering climate being unfavourable to inventors and new thought in Great Britain. There were, of course, exceptions to this, the main one being Harry Ferguson who was one of the few people who understood what opportunities and facilities were necessary in order to stimulate new ideas. One result of this was the trailer hitch which for the first time made unbalanced trailers practical and was copied throughout the world within five years. Since the early 1950's very few fundamentally new ideas have come from industry—the exceptions such as the flail harvester emanated from the U.S.A. and the drum mower from Germany.

The post-war problem in our industry was that the new tractors and implements formed part of a system. The major companies tended to manufacture and sell their whole system and this made hundreds of pre-war implements and their manufacture redundant. This change involved capital expenditure of millions of pounds and so favoured the large firms since they alone could afford to invest in tooling for large scale production. This was also a period of rapidly rising living costs and those engineers with inventive abilities were attracted to the big companies by better salaries while others left the industry altogether, in search of higher rewards.

This has left the agricultural industry with half a dozen world-wide organizations who between them represent probably 75% of the whole turnover and a host of smaller companies many of whom now act as import agents for European equipment as they are unable or unwilling to generate and support their own developments. This must *not* be allowed to reflect on those companies who *have* shown initiative. One wishes there were more of them.

Thus in spite of the formidable achievements of our tractor industry, the overall balance sheet is marred by implement imports most of which could be designed and made in this country. This situation, which will become critical for our industry in the future, is largely caused by unimaginative top financial control. It is commonly believed that one can lose money faster with mad inventors than one can with fast women. This idea comes from non-technical management who do not understand how to control a development programme.

One of the major problems for the inventor is that of obtaining capital to finance his work. Many companies are loath to employ such an individual because of the fear of what it will cost. Alternatively many inventors cannot work with the meagre facilities offered by some companies. A few of them will try to develop ideas on their own but they soon discover that this is usually very costly. Outside financial support, if secured, involves almost complete surrender of control of the project. This impasse must be overcome if, firstly we, as a nation, are to start making full use of our natural ingenuity and, secondly, we want to stop the brain drain.

Another aspect of this problem is the commonly held view that it is much better to take a foreign licence out for a proved process or machine than to develop our own. This is only a short-term outlook and is responsible today for an enormous drain on our foreign currency.

Even more frustrating is the situation in which the initial idea has been thought up in the U.K. and, because money is not spent here on its development, this takes place abroad, often in the U.S.A. We then have finally to take a licence to manufacture the finished product because of development patents taken out abroad.

Through our educational system we are today training thousands of young people in a wide range of technical subjects. On the natural law of averages a proportion of these could become inventors and yet under, present circumstances, not 1% of them are likely to achieve success in this field. This is a national disgrace because we need these inventors to infuse new life into all our industries, to enable them to hold their own in world markets. Instead, many of these industries fight to retain a shrinking percentage against countries like Japan. The solution to this problem lies not in national corporations but rather in fiscal encouragment by providing tax incentives specifically for new research and development work which has export potential. This would provide the right climate in which companies could feel encouraged to give more financial priority to new work, thereby creating a demand for the inventor.

This is an outline of what should happen. Whether anything is done or not is a political decision, and at the moment the outlook is not hopeful. Our country has a proud record of inventors over the last few centuries. Let us try to maintain this record and profit by so doing.

INTERNATIONAL AGRICULTURAL AVIATION CONGRESS

Canada will be host in 1969 to the fourth International Agricultural Aviation Congress. The Congress, the first in North America, will be held at Queen's University, Kingston, from 25th to 29th August. The theme of the conference will be 'Progress Through Co-operation'. Its purpose will be to facilitate exchanges of information, thereby contributing to international progress in agricultural and forestry aviation, and to promote co-operation in research, technology and operations.

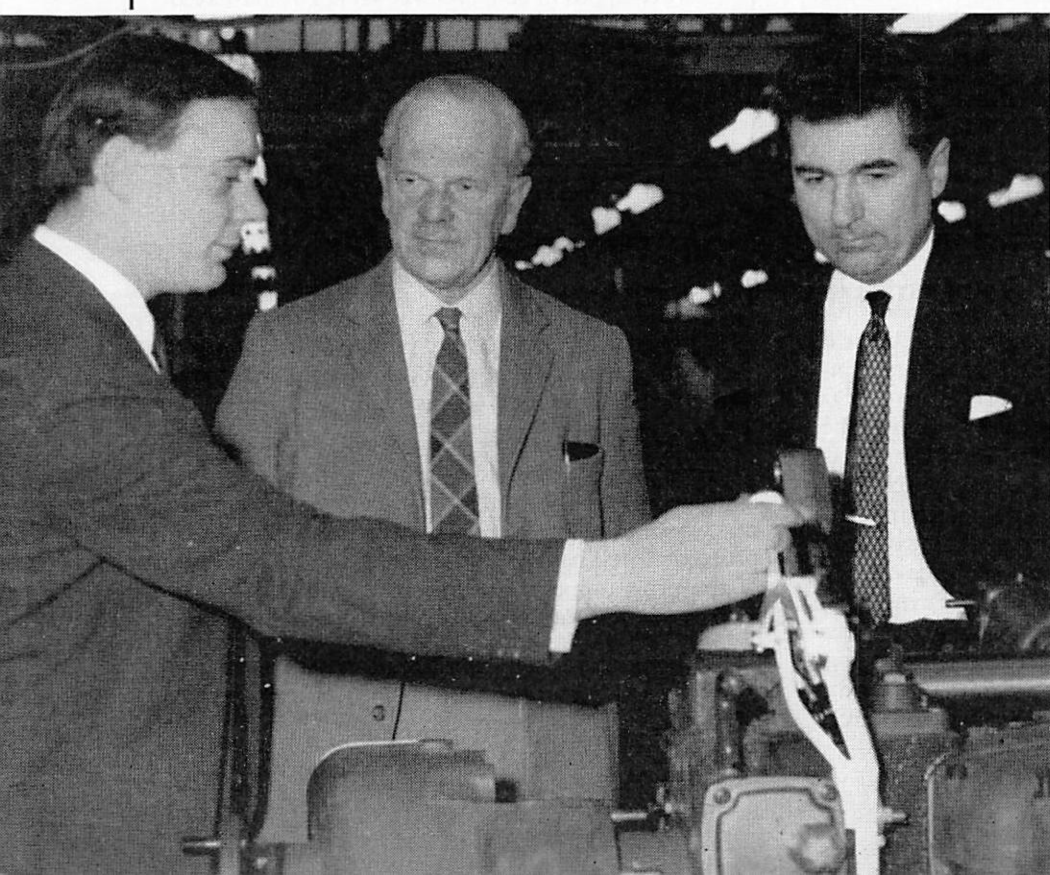
Further information can be obtained from the Congress Secretary, Mr M. K. Ward, National Research Council, Ottawa, Ontario, Canada.

New International Glossary will help talks on Soil

In a search for a uniform nomenclature for a world soil map which is being prepared for experts of many tongues by the Food and Agriculture Organization and the United Nations Educational, Scientific and Cultural Organization, new short terms are being sought which will make the map's meaning clear to all. For example, the word "lateritic" referring to soils or weathered materials rich in iron which harden on exposure, had gradually come to mean all red and yellow soils of tropical regions. Now the name "ferralsols" with a precise definition has been proposed to describe some of those red and yellow soils.

The new terms are listed in a publication, distributed by FAO recently, which was used as a basis for the legend of the first draft soil map of the world presented at the Ninth International Congress of Soil Science in Adelaide, Australia, 6-16 August, where the proposed nomenclature and definitions discussed. The map will provide one of the keys to the complex questions of how and where to grow crops of various kinds, and will help in the effective transfer of agricultural knowledge and experience from one area to another. The first draft is the result of eight years' work by FAO, UNESCO and hundreds of soil scientists around the world.

President and Secretary at Meltham Tractor Works



The President, Mr T. Sherwen, and the Institution Secretary, Mr J. K. Bennett, visited the Meltham tractor factory of the David Brown Corporation whilst in the area for the A.G.M. of the Yorkshire Branch of the Institution in March. They were welcomed by DBT Market Research Manager, Mr T. H. E. Harrison, who is also the Institution's Yorkshire Branch Hon. Secretary-Treasurer.

Photograph shows the President (centre) with the Secretary (right) in company with Mr P. Hulbert, DBT Field Instructor, on a tour of the works where they saw the Selectamatic range of tractors in production.

Publications Received

The following publications have been added to the Institution Library.

Cotton Varietal Characteristics Affecting Mechanical Picking and Ginning—by CHARLES S. SHAW, GARY L. BARKER and JOE E. CLAYTON (United States Department of Agriculture, Agricultural Research Service)

A series of yearly experiments was begun at Stoneville in 1962 to establish quantitative measurements of cotton plant characteristics that affect mechanical picking. In discussing plant characteristics as they affect harvester performance, engineers and plant breeders have heretofore commonly relied on qualitative terms. Research was done in a series of continuing studies to establish more measurable definitions of desirable plant characteristics for mechanical picking. Although a number of parameters was measured, the primary effort in the early experiments was to relate lock-removal forces to harvesting efficiency.

★

British Standard 1841: 1968. Attachment of Mounted Implements to Agricultural Wheeled Tractors

This British Standard was originally published in 1951 to promote the maximum degree of interchangeability of use between tractors and tractor-mounted implements, and as a guide to the manufacturers of mounted implements. The present edition now includes a Category 3 three-point linkage system, recommended for wheeled tractors of 80 drawbar horsepower upwards. Additional data which is essential to the achievement of complete interchangeability between implement and tractor has also been included. Category demarcation has now been related to drawbar horsepower based on the test laid down in BS1744.

★

British Standard 2687: 1968. Specification for Agricultural Discs

First published in 1955, this Standard was prepared with the object of reducing the large number of different sizes and designs of discs in use. Adoption of this Standard will afford not only the benefits of rationalization in manufacture and storage, but also the advantages of interchangeability and the assurance of quality of the discs both in machine building and in use. In formulating the Standard care was taken not to restrict in any way the development of improved materials for disc manufacture nor the freedom of the designer of the disc. The main purpose of this Standard is to provide for a minimum number of types and sizes of discs to meet the requirements of a wide range of conditions of work.

President Appeals for More Support for Endowment Fund

REFERRING to the Institution's 30-year Anniversary Endowment Fund, launched twelve months ago with an immediate target of £10,000, Mr T. Sherwen, President, speaking at the Annual General Meeting of the Institution of Agricultural Engineers, held in London on 9th May, warned members that unless the money was forthcoming the future of the Institution as a thriving body, well served by a permanent executive, was in jeopardy.

Although it was most encouraging to note that as a result of a further appeal sent to members in the form of an open letter a sum of about £1,300 had been received, most of this had come from anonymous sources and only about two per cent of the total membership had actually contributed.

'We cannot have an Institution whose future is dependent on the generosity of 2% of its membership', said Mr Sherwen. 'Our anonymous benefactors have given us a head start on our road towards the immediate target of £10,000, but now it is up to the 98% of us to find some of the rest. Surely, if you find that the Institution gives you enough benefit, pleasure and interest for you to pay annually to be a member, you can find a small sum of money in this one year to secure its future for yourselves and your successors. The Institution has fought hard for the recognition it now has among its peers. But it cannot continue to hold its head high in poverty. It has gone beyond the stage when it is young and able to live on a shoe-string in a 'sweater and jeans' sort of way. It is mature, and must act in a mature way. It must pay its own corner. It must enter the lists of public affairs fully equipped to do a professional job. It must keep up the appearances of a professional body—and without financial security it can do none of these things.'

Spring National Meeting 1969

Planning and Executing the Development of Agricultural Resources

The Spring Open Meeting of the Institution is to be held next year at the National College of Agricultural Engineering, Silsoe, Bedford, on Thursday, 27th March. Dr P. C. J. Payne, MSC, PHD, MI AGR E, MASAE, Principal of the College and a Council member of the Institution, has kindly agreed to be Convenor of the meeting, which is to have the general title of Planning and Executing the Development of Agricultural Resources. It is expected that four papers will be presented, the conference closing with a forum under the chairmanship of Dr Payne.

The meeting is the second in the series entitled 'The Contribution of Agricultural Engineering in Developing Countries'. The first was at the Spring National Meeting of the Institution at the University of Reading in March 1967, when three papers were presented on the mechanization of agriculture in semi-arid territories (published in the Autumn Winter 1967 issue of the **Journal**).

The first part of the programme will deal with progress in techniques for planning the use of land resources for agricultural development. The second will give examples of two contrasting types of developments that have proceeded well beyond the planning stage. The final part of the programme, the forum, is intended to widen the interest outside the matters dealt with in the papers.

It is expected that a number of organizations will be able to provide an interesting display of instruments and photographs used in air-photo interpretation. Full details

ANNUAL DINNER OF THE INSTITUTION 1968

ENGINEERING – THE 'SILENT SERVICE'

says Wedgwood Benn

'We don't hear enough from the engineers themselves', said Mr Wedgwood Benn, Minister of Technology, proposing the toast of 'The Institution of Agricultural Engineers' at the Institution's annual dinner, held on 9th May at St Ermin's Hotel, London. 'It is all very well being the silent service . . . but don't forget that if engineering is to be regarded in the way that we must regard it if we are to get engineers and use engineers, it does involve rather more from the engineer than we have heard. If you made trouble with a capital 'T' there would be a round of applause in the Ministry of Technology because at last we would think that things were moving', concluded Mr Wedgwood Benn amid laughter.

Contribution to Import-Saving

The Minister, principal guest at the dinner, which was attended by about a hundred members of the Institution and their guests, had previously spoken of the relationship that existed between the members of the Institution and himself as the Minister of Technology. Each in his own way was focussing upon the problem that faced Britain today, that of trying to sell abroad as much as it wanted to buy abroad. 'Until we do sell more abroad and save imports at home', said Mr Wedgwood Benn, 'this problem is going to remain with us, and this is the problem absolutely central to the agricultural engineer. We still pay approximately £1,500 millions a year for food imports. We have the most mechanized agriculture in the world; this is the product of the agricultural engineer. Your work fits centrally into this class of import-saving and in the process of developing machinery to do this you sell more abroad, and therefore you contribute to the other side of the equation. I want to say "thank you" for this aspect of your work'.

Institution's Varied Problems

In welcoming Mr Wedgwood Benn to the dinner the Institution's President, Mr T. Sherwen, said there may well be an occasion in the future when a 'friend at court' who was aware of the Institution's special problems could be a great help.

The Institution represented a fast-moving industry and in doing so embraced a wider spread of disciplines than most other similar bodies. This meant that the Institution's problems, as the qualifying body for the industry, were more varied and widespread than usual. This situation had given rise to anxieties, that too much attention was being paid to the professional engineer and not enough to the technician. This was not so, but perhaps that impression had been gained because while the requirements of the chartered engineer were settled and well known, those of the technician were still being decided.

The Institution's principal guest, the Rt. Hon. Anthony Wedgwood Benn, Minister of Technology, and the President, Mr T. Sherwen

The Institution of Agricultural Engineers was intimately concerned with the future of both levels of engineers, as well as those who were climbing the ladder towards those levels, and the Institution would always work to maintain the status of the agricultural engineer relative to his counterpart in other industries. These and allied problems made it essential for the future role of the Institution to be considered very carefully and to this end a working party had been set up to advise on these matters.

No Official Financial Support

The President went on to describe some of the services performed by the Institution for the industry. As well as being the learned society of the industry, it ran the qualifying examinations and acted as the official United Kingdom representative of C.I.G.R., the international body of agricultural engineering, and all without any official financial support.

'Mr Minister', said Mr Sherwen, 'you might think that I am doing a little axe grinding. I am. Today we are passing through a period of extreme stringency which makes it almost impossible to run institutions such as ours in a viable financial manner. I have no hesitation in saying that we would welcome any official financial support for our official activities'.

Mr Sherwen, in conclusion, said the Institution had a big part to play in the future of the industry. The industry provided the tools for the farmer to produce our food. The increase in productivity by farmers since the

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ANNUAL CONFERENCE 1968

THE APPLICATION IN AGRICULTURE OF PRODUCTS DERIVED FROM PETROLEUM

The Annual Conference of the Institution was held on 9th May at the Institution of Mechanical Engineers, Birdcage Walk, London, nearly ninety delegates attending. The theme of the conference this year was 'The Application in Agriculture of Products Derived from Petroleum', the following papers being presented:

'The Use of Hydrocarbon Oils in Agricultural Sprays'—Dr C. G. L. Furmidge, PHD, BSC, FRIC (Head of the Physical Chemistry Division, Woodstock Agricultural Research Centre, Shell Research, Limited);

'Petroleum Products in Soil Conservation'—Mr E. W. Lang, BSC(ENG), AMICE (Technical Services Branch, BP Trading Limited);

'Engineering Aspects of Ammonia Injection as developed in France'—M. Jean Caupin, Ing, ENIA (President L'Ammoniac Agricole).

Chairman for the morning session was Mr E. Atkinson, C ENG, AMI MECH E, AMI AGR E, Hon. Treasurer of the Institution, while Mr E. S. Bates, MI MECH E, MEM ASAE, F INST PET, MI AGR E, was in the chair for both the afternoon session and the closing general discussion.

The full text of the three papers and the ensuing discussions are to be published in the next issue of the *Journal;* this will be the Autumn-Winter issue, due to be published towards the end of this year.

ANNUAL DINNER OF THE INSTITUTION 1968

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war had been roughly three times, and this was way above the national average. The Institution was proud of the part its members had played in this achievement.

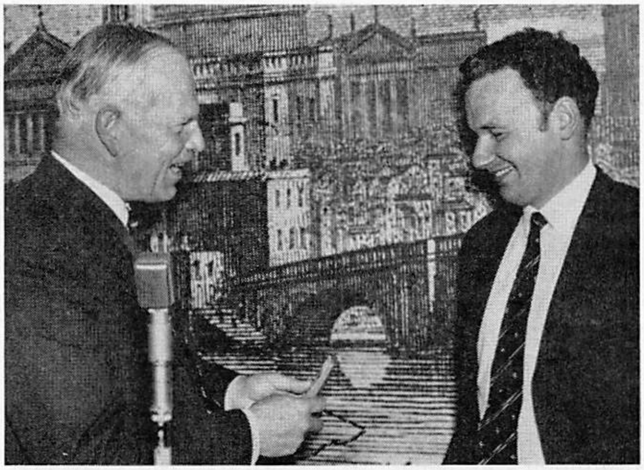
Guest Speakers

Mr J. A. C. Gibb, Vice-President, proposing 'The Guests', mentioned in particular Dr C. G. L. Furmidge, of Shell Research Limited, Mr E. W. Lang, B.P. Trading Limited and M. Jean Caupin, president of L'Ammoniac Agricole, who had all been guest speakers at the Institution's annual conference held earlier in the day, the theme of which had been the Application in Agriculture of Products Derived from Petroleum.

Mr Gibb also introduced Mr C. C. F. Laidlaw, a director of B.P. Trading Limited, who responded for the guests saying however good the progress the oil companies made in the development of new products, they were totally dependent on agricultural engineers for the design of the machines that would use these in the most economical way and translate their dreams and hopes into reality. The oil industry had for many years now lived very closely with the most complex operations research and on this side they should have rather a lot to contribute.

Johnson Medal Winner

During the evening, the President presented the Johnson Medal to Mr J. N. Lawton for his achievement in last year's National Diploma in Agricultural Engineering examinations. The award, made annually commemorates the foundation of the Institution in 1938 by the late Lt.-Col. Philip Johnson, first President of the Institution.



The President presents the Johnson Medal to Mr J. N. Lawton, the 1967 winner of the annual award

The 1967 winner, Mr Lawton, is 29 years old and became a Graduate Member of the Institution at the beginning of this year. He has been lecturing on work study, materials handling, systems engineering and related subjects for the farm management course at Seale-Hayne Agricultural College, Devon. Mr Lawton gained a distinctions in three out of four subjects of the diploma examination, his success being especially noteworthy as he was the first ever external candidate to be awarded the medal.

ENGINEERS, TECHNOLOGISTS AND SCIENTISTS IN THE NATIONAL ECONOMY

Report of a Joint Committee on Professional Manpower comprising representatives of the Royal Society, the Confederation of British Industry, the Council of Engineering Institutions, the Institute of Physics and the Physical Society, the Royal Institute of Chemistry

One of the many significant conclusions reached by the Joint Committee on Professional Manpower, under the chairmanship of Sir Eric Mensforth, CBE, of the Council of Engineering Institutions, in its recently published report was that professional institutions must identify themselves more fully with political, sociological and economic matters having a high scientific, technological or engineering content. The report includes recommendations to Government, industry, the professional institutions, universities and schools in its searching analysis of present and future trends in the United Kingdom of technology engineering and the associated industries.

The Joint Committee comprises nominated representatives of the Royal Society, the Confederation of British Industry, the Council of Engineering Institutions, the Institute of Physics and the Physical Society and the Royal Institute of Chemistry, and their immediate task was to condense and summarise the findings and recommendations contained in a number of, relevant reports recently published in Britain. 'Failure to accept the findings', says the Committee, 'will inevitably have adverse consequences'.

The Report begins by stating that in a world in which engineering, technology and science play an increasingly dominant role, the prosperity of Britain with its limited natural resources depends more than ever before on the skill of its population. The proper education, training and optimum utilization of its manpower is therefore vital. There is strong evidence for anxiety as to the recruitment, supply and use of scientists, technologists and engineers who create the knowledge and organize the human effort required for its successful exploitation in industry and commerce upon which our whole economy depends. These three highly skilled professional groups are interlinked and interdependent.

BACKGROUND

The money to pay for all our national, communal and personal activities, continues the report, is earned mainly by production—in mining, agriculture, etc. and predominantly in manufacturing industry. These together employ less than half the working population, itself less than half the whole. The remainder are in service occupations such as transport and communications, distributive trades, health, education, local and national government—all essential to community life, but basically dependent on production. To maintain and develop our relatively high standard of living in a sternly competitive world requires highly-skilled and experienced technological and engineering backing. This is mainly provided by a small number, 360,000, of professionally qualified engineers, technologists and scientists, who comprise no more than 1 in 70 of the working population. These people carry a major responsibility for the prosperity and standard of living of the nation and not least for the nation's ability to make an effective contribution to the solution of the world's social and economic problems.

Change is now more normal than stability. Engineering and technology and their associated industries can become obsolete in a decade. Survival demands innovation, but new ideas only create wealth when commercially exploited. This requires a climate in which the role of technology and engineering is understood and in which the personal and capital risks of development are accepted as socially desirable and necessary.

The evidence of recent reports points to a serious shortage of highly qualified manpower. Although the annual output of these people has risen by more than 50 per cent in the last decade, important sections of industry have not been able to meet their requirements. The position is now worsening as the current 'swing away from science' in the schools jeopardises the future supply. Engineering, technology and science are not securing sufficient of the best brains. The reasons for this turning away from scientific and technical studies by abler students have been given as unimaginative teaching in the schools, the apparent lack of humanity of science and its concern with itself rather than its implications for society. There also appears to be insufficient understanding of the whole involvement of human values in industrial careers.

Added to all this there has recently been a large increase in emigration from the U.K., equivalent in 1966 to 42 per cent of the supply rate of engineers and technologists and to 23 per cent of scientists. Not only numbers but quality are lost. Amongst the reasons given for emigration

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ENGINEERS, TECHNOLOGISTS AND SCIENTISTS IN THE NATIONAL ECONOMY—*from previous page*

are the apparent reluctance of large sections of industry to give full rein to the abilities of new entrants and the delay in attaining comparable rewards. Environment and political factors, such as undue emphasis on equality at the expense of excellence, doubtless also play a part. Each of these emigrants reduces our national productive capacity and increases that of our competitors. This drain of qualified manpower, if continued, will be seriously harmful to our economy. To stop it requires not physical controls but that this country should offer an attractive environment and appropriate reward to a body of people who must be recognized as being internationally exceptionally mobile.

CONCLUSIONS AND RECOMMENDATIONS

The Report goes on to list the following conclusions and recommendations:

Government

(a) Political parties should take positive steps to see that Parliament itself is properly equipped to understand the social and economic implications of progress in technology and engineering.

(b) An adequate proportion of qualified engineers, technologists and scientists must be included in the Administrative Civil Service at policy and decision-making levels.

(c) The conduct of national projects with a high technological and engineering content should be such that the nation, including its young people, feel that there is a sense of decisive purpose and something worthwhile for which to work. Annual progress reports should be published.

(d) Government should foster a climate in which adequate provision can be made for risk finance for research and development projects of potential long-term benefit, and for their commercial exploitation.

Industry

(a) Industry must 'sell itself' better. It must show more clearly the challenge and opportunities offered at many levels to creative ability and to initiative; that it encompasses not only fascinating techniques, novel machines and highly sophisticated processes, but above all concern for human beings and the satisfaction of their needs. It must demonstrate that industry provides jobs which are nationally important and personally rewarding.

(b) Much of industry does not yet know how to use effectively the products of the educational system. In future its professionally qualified recruits will normally be graduates. The pattern and character of education are changing, but for the changes to be fully effective industry must play its part in defining its needs. This raises no difficulties for the large science intensive firms, but adaptations and changes of attitude will be required in many medium-sized and small firms, particularly within the traditional industries.

(c) Industry must find new ways to help the graduate to make the transition to a productive engineer or technologist. More widespread attention needs to be given to the induction of graduates into industry by intensive and systematic teaching of the techniques, economics and sociology of manufacturing processes, rather than by a process of casual observation.

(d) More use should be made of scientific career ladders so that a man has not necessarily to go into business management to secure the highest rewards. Industry must demonstrate that design and production offer challenges and satisfaction every whit as great as those of research and development—for scientists as much as for engineers and technologists. It must be seen that engineers, technologists and scientists play a full part in the formulation of company policy and objectives at all levels.

(e) If it is to compete with for example the U.S.A., industry must recognize outstanding merit by offering such people higher than normal rewards, particularly early in their careers.

(f) The larger firms should examine more critically the career structure of their qualified men. There is evidence that in the 35-45 year age groups many are under employed in undemanding positions. Industry should adopt a transferable pension structure which would permit such men to move to teaching or to other firms where they could be better utilized.

(g) Co-operation in Britain between Industry and Universities, taken as a whole, lags considerably behind that in other major industrial countries. Contacts and co-operation between Industry and Universities and Technical Colleges should be increased. Industry should involve more University staff in their affairs. They should encourage the Universities to appoint people from industry as visiting professors and lecturers.

Professional Institutions

(a) The Professional Institutions should accept the merit of a broader first degree, with thereafter, and often after practical training in industry, further relevant specialist studies. Entry to Institution senior membership grades could well be dependent on evidence of participation in appropriate postgraduate study. It is now becoming apparent that periodic study and training will be necessary throughout a career to maintain technical and managerial competence. The Industrial Training Boards should assist in stimulating and supporting such re-education and retraining.

(b) The Professional Institutions must identify themselves more fully with political, sociological and economic matters that have a high scientific, technological or engineering content.

Technical Information for Engineers: What they need and what they get

A joint one-day C.E.I./Aslib Conference entitled 'Technical Information for Engineers: What they need and what they get' will be held at the Institution of Mechanical Engineers, Birdcage Walk, London, on Thursday, 10th October, commencing 9.30 a.m.

The Conference will attempt to assess the technical information needs of engineers, relate these to existing services and try to determine what services not already in existence would be desirable in the future. Conference particulars may be obtained from Mr R. S. Glynn, Institution of Mechanical Engineers, 1 Birdcage Walk, London, S.W.1.

ENGINEERS, TECHNOLOGISTS AND SCIENTISTS IN THE NATIONAL ECONOMY—*from previous page*

Universities and Schools

The report continues by stating that universal higher education is made possible by the successful exploitation of modern industrial engineering and technology and it must in turn provide enough engineers and technologists to ensure an economic situation adequate to meet the costs of this generous educational provision. The nation cannot afford free university education in every chosen discipline for all who can achieve minimum entrance requirements and consideration may have to be given to some bias towards those disciplines that economic facts dictate are essential to community needs.

In the schools, beginning at the earliest possible age, as many children as possible should obtain an appreciation of the scientific and technological background of the society in which they are living. At present there is a dangerous 'swing away from science' in the schools. The number of final year sixth form students in the science group, from which the undergraduate scientists, technologists and engineers have traditionally been drawn seems likely to fall from a peak of 40,000 in 1964 to 31,500 in 1971, whilst other groups increase from 67,000 to 103,000.

The decision to read 'science' has at present to be taken too early at school, where in any case there is often a bias towards arts, often due to inadequately qualified advice on the science side, and particularly to lack of understanding as to the nature and scope of its applications in engineering and technology.

The report concludes by saying that in schools the funds available for the teaching of science vary considerably but are generally inadequate. Compared with expenditure on higher education, adequate funds would make only marginal demands on resources. The authorities, backed by Government, must recognize that this is false economy and remedy the stituation.

Open Meeting on Systems Engineering in Agriculture

An open meeting on Systems Engineering in Agriculture is being planned for September. The one-day meeting, which promises to be especially well attended, will take place on Thursday, 26th September, starting at 10 a.m. The venue will be the Palmer Building of Reading University, which houses a spacious and fully equipped lecture hall with seating capacity for four hundred.

The main programme of the meeting will consist of the presentation of three papers, each followed by discussion. An open forum to discuss applications of systems engineering in agriculture will conclude the main programme scheduled to finish at four in the afternoon, with a panel consisting of the authors of the three papers: Professor J. F. Coales ('An Outline of Systems Engineering'), Dr Donnell R. Hunt ('A Systems Approach to Farm Machinery Selection') and Professor J. R. O'Callaghan ('The Systems Approach to Engineering Design'). The three authors will be joined on the panel by an industrial systems engineer and the chairman for the forum will be Mr K. E. Morgan (University of Reading).

A subsidiary programme to follow the main programme is also being arranged by the convenor, Mr J. A. C. Gibb, Vice-President of the Institution and Senior Lecturer in Agricultural Engineering at Reading University, which will include an open afternoon at the Department of Applied Physical Sciences, Reading University, to see work on instrumentation, control systems, cybernetics, tribology, and other related subjects. There will also be demonstrations of digital computer operation, in the computer Unit of Reading University.

The date of the meeting usefully falls within the normal vacation period of the University, and there will be ample car parking. The Students' Buttery offers excellent facilities for lunch and is only 200 yards from the lecture room.

SYSTEMS ENGINEERING is a new approach to the solution of problems of design, management, selection and distribution, which has already proved to be of great value in many industries. It includes the use of such techniques as Critical Path Analysis, Network Analysis, Mathematical Modelling and Simulation studies. It may depend on the use of computers in the analysis of real-life situations, the synthesis of theoretical solutions and selection of the best alternatives for practical application.

The conference will enable agricultural engineers and those with related interests to discuss the possibilities of Systems Engineering and its practical applications in agricultural engineering design and in agricultural mechanization.

Details of the full programme for the day are shown on page 84.

NEW MINISTER APPOINTED

It was announced on April 5 that Mr Cledwyn Hughes, 51-year-old Secretary of State for Wales, was to be Minister of Agriculture, Fisheries and Food, in place of Mr Frederick Peart, who became Lord Privy Seal and Leader of the House of Commons.

Scholarship Awards in Agricultural Engineering

The Institution announces the following Scholarships to full-time students of Agricultural Engineering during 1967-68

WINNER OF THE DUNLOP SCHOLARSHIP

The Dunlop Scholarship for 1967 was awarded to **Mr A. L. GROCOTT,** aged 23, of Ropley, near Alresford, Hampshire. Mr Grocott was at Christ College, Brecon, from 1958-63, going on to Loughborough University of Technology where he gained a Diploma last year having completed the four years full-time course in general engineering. Since being awarded the scholarship last October, Mr Grocott has been studying at the National College of Agricultural Engineering, Silsoe, Bedford.

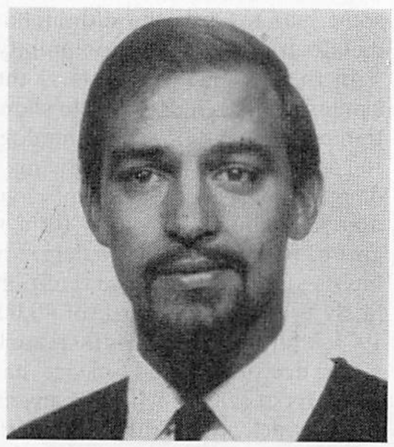
A. L. Grocott

SHELL-MEX & B.P. BURSARIES AWARDS

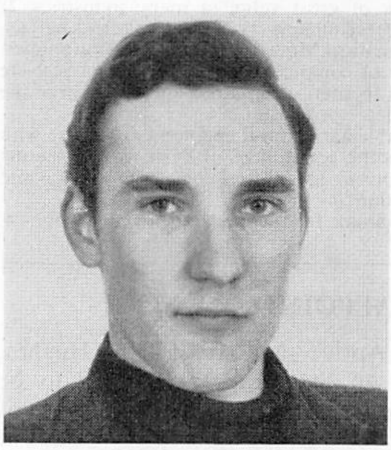
J. W. Packard

Mr J. W. PACKARD, of Corsham, Wiltshire, was one of the 1967 recipients of a Shell-Mex & BP Bursary. Educated at St Albans School, Hertfordshire, and the Warwickshire Institute of Agriculture, Mr Packard, after some dairy farming experience in Cheshire, joined the Government Department of Agriculture, Tanganyika, serving there as a member of HMOCS for 14 years. Returning to the U.K. in 1965, Mr Packard, who is 41, married, with one child, followed the courses at Lackham College of Agriculture leading to the award of the C & G 260 and 261 Certificates. A Student Member of the Institution, Mr Packard is studying for the ND AGR E at the Essex Institute of Agriculture.

Also now studying at the Essex Institute of Agriculture, Writtle, for the ND AGR E. is **Mr R. O. A. DREW,** who gained his NDA last year at the Royal Agricultural College, Cirencester. Mr Drew, who is 24, went to Caterham School, Surrey, representing his school at cricket, rugby and hockey. He is also a keen swimmer. Mr Drew was another recipient of a 1967 Shell-Mex & BP Bursary and he became a student Member of the Institution at the beginning of this year. His home is at Seaford, Sussex.



R. O. A. Drew



R. T. Evans

Mr ROGER EVANS is from Anglesey, where he attended the David Hughes County Secondary School at Beaumaris. After leaving school he did some practical farming from 1963 to 1965 and also studied at Pencraig College, Llangefni, Anglesey, going on to the Royal Agricultural College, Cirencester, where he gained the NDA in 1967. Mr Evans, who is 21 years old and a Student Member of the Institution, is also taking the NDA AGR E course at the Essex Institute of Agriculture following his successful application last year for a Shell-Mex & BP Bursary.

MECHANIZATION OF CATTLE FEEDING

THE CASE FOR SIMPLICITY IN THE MECHANIZATION OF CATTLE FEEDING

by

REX PATERSON, CI AGR E*

Presented at the Annual Conference of the Institution on 11 May 1967 in London

The examples of simplicity in cattle feeding quoted in this paper are based on methods of milk production used by myself and other farmers on an extensive scale for many years. They depend on the use of grass which is grazed in the field for about seven months in the year, and self-fed from stacks of silage cut from surplus grass, during the winter.

An important feature of these methods is that no other labour is employed, other than that which is required to milk the cows and look after the young stock, even when these are kept in the largest units which are considered necessary for economical production.

It is commonly found that whatever methods of milk production are employed, when allowances are made for sickness, holidays and all other work, the average number of cows milked for every man employed is seldom more than 50. In our experience this staff may be organized on the basis of two men for 100 cows, three men for 150 cows or it could be represented by two neighbouring farmers with 50 cows each who assist each other. Although stock require attention seven days per week, the average hours worked per week should not exceed about 45.

On a grassland farm liberal use of fertilizers, particularly Nitrogen, is important, with regular applications after each grazing or cutting being applied. This however need not be a major task for tractors, with machines now capable of sowing 10 acres per hour from bulk stores. Conservation of surplus grass as silage to provide both a continual supply of good grazing and winter feed can demand power and machinery at the rate of 2 hours per acre, with perhaps two cuts being taken in the year.

The importance of good access between all parts of the farm and the points of storage for both fertilizer and silage is emphasized, and the important features of the machinery used are discussed.

Grow no other crop than grass

There is no crop likely to give either cheaper, or more abundant feed in most areas of Great Britain than grass, if it is well fertilized and managed. There are, of course many situations where grass may be alternated with other crops, but for simplicity and economy in cattle feeding there is no better crop than grass alone. Few other countries have better climates and soils for the growth of grass. Therefore we should exploit these advantages to the maximum extent of our market for livestock products.

Minimize the movement of men, stock and materials

The great advantage of grass is that stock can graze most of it where it is grown, and leave their dung and urine on the fields. This is only possible if the grass is accessible. In the case of milking cows they cannot walk more than about 800 yards to a pasture without undue loss of time. Therefore it is important to lay out a farm so that grazing paddocks are within this distance. Similarly, the paddocks should not be more than 300 to 400 yards long, or they will be too big, or too narrow for good grazing. This usually limits the area conveniently reached to 100 acres in either direction from a milking shed.

If there are no more than 100 acres available, the herd size is unlikely to exceed 100 cows, unless feed is brought in from other areas. It is of course possible to restrict the grazing to nearby areas to provide grazing for more cows within reach of a milking shed, but we prefer the advantages of alternating grazing and cutting over the same area. We also prefer to have only one man in charge of each herd. As one man can milk 75 to 100 cows, this combination of area, cows and staffing meets our requirements. It also reduces the problems of overtreading lanes, gateways and paddocks in very wet weather, and is more convenient for self-feeding in winter.

Whenever possible we like to provide a central cattle lane giving access to all paddocks. Where each sub-division fence meets the access lane a gate is provided in the sub-division fence, and adjacent to the lane. These gates can be open when the paddocks are not in use so that all tractor traffic can move quickly to any paddock on the area.

THE FIELD EQUIPMENT

Fertilizer Spreader

In some areas the most economical grass yields can be obtained from the use of adequate Phosphate and Potash and a moderate use of Nitrogen. In other areas heavy and frequent dressings of Nitrogen may be the main necessity. On a large farm where several herd areas require an application of Nitrogen each time a grazing is completed, this becomes a priority task on the farm. It can easily involve the handling of 12 cwt or more fertilizer per acre divided between five or six applications.

Please turn to next page

* Farmer

THE CASE FOR SIMPLICITY IN THE MECHANIZATION OF CATTLE FEEDING—

from previous page

We have minimized the labour required for this work on large farms by building Dutch Barns 30 ft wide by 45 ft long and 18 ft to the eaves. These are fully enclosed on three sides, with the end least likely to suffer from rain, left fully open. Fifteen ton loads of bulk fertilizer are easily dumped into these buildings and piled, if necessary, with a tractor 'pusher'. Normally there is no piling necessary except for winter storage where up to 200 tons can be stored per shed. The two wheel bulk handling fertilizer spreaders which we use can be loaded in less than three minutes using a rear mounted hydraulically operated loading bucket. This combination of no doors, few gates to open, and no manual handling of the fertilizer makes a tremendous contribution to the ease and speed of applying fertilizer to large areas of grass for the cows to self feed either in situ or from the silage stack.

The Forage Harvester

Overall, in England and Wales, we have nearly 7,000 acres of grass, a high proportion of which is cut twice each year. Cutting is done primarily to maintain the grass in condition for the sequence of future grazing, and equally to provide winter feed. Over the past years feed had to be provided for five months in the winter, but this is being reduced to four months by the use of extra Nitrogen.

Silage conservation is another task where we require the highest output per man that we can get. The extra man in each team of three (i.e. two milkers and one othertman) usually does all the cutting. He starts cutting as soon as he is ready in the monring, and cuts until about eight o'clock in-line forage harvester with atrailer permanently attached behind. Between about 18th May and mid-June he takes all loads to wedge stacks built next to the milking sheds, where he drops them from his trailer at the stack, preferably without stopping. He will usually average from two to four loads per hour. Grass cut after mid-June is stored elsewhere for dry stock. Most areas are cut twice per year as well as being grazed, and all areas are grazed in the Spring before a cut is taken.

Tractor Power

We have used both 40 in. and 52 in. cut forage harvesters and, in spite of the extra power required, we prefer a high rotor speed, because this enables us to carry up to twice as much grass in a trailer. In the past the output per hour in tough cutting was often no more with a wider cut than with a narrow cut, due to lack of power. However, some years ago we fitted Fordson tractor engines on those forage harvesters which had to work on hills, and this increased the output markedly. Hills make a grea difference to the tractor power required to pull a heavy load of grass at the same time as they are cutting.

There is less necessity to fit an engine on the forage harvester no that we have more power in our tractors The ability to change gear when going uphill without stopping the newer tractors also contributes to an increased output.

Several of our forage harvesters have given many years service with remarkably little trouble. Stony ground caused damage to the original flails, but the better quality material now used gives them a very long life. The forward heavy trailers, with wheels at the rear, put a considerable load on the forage harvester wheels. We are now putting the original three ton trailer wheels on the forage harvesters, and fitting four ton tyres on the trailers.

The Trailer

The chassis of present day trailers are strong enough, but the original bodies have proved inadequate for the high speed work with silage. Vibration and fractures gave considerable trouble until we built the bodies with the top slightly narrower than the bottom. We also closed in the top so that we could throw the load from the forage harvester against it in front. The effect of these changes was:

(a) It stopped all side sway of the body.

(b) The settled loads slid out more easily.

(c) By the combination of higher velocity, and the delivery of grass on the underside of the roof, the trailer was more full loaded. This also made it possible to have a shorter chute on the forage harvester, which reduced the risk of fracture.

As mentioned earlier we now fit heavier tyres on the trailers, and have widened the axles. The overall width of the outside of the tyres should be 6 ft 3 in. to 6 ft 6 in. to improve stability.

The trailer body hinges must be strong, and the body should also return fairly quickly after tipping. The rear door should be top hung and shut inside the body. This also helps the stability of the body. It must also have an adequate self-opening and closing device.

Consideration of all these points will save an immense amount of time.

The Buckrake

The grass is stored in self-feed wedge stacks. Although one forage harvester cuts on alternate days for two herds, we have found it necessary to increase the width of stocks to give room to store grass at increasing speeds. All stacks are built in the open, and the fact that the grass dries while waiting to be stored, and on the stack surface, makes it unnecessary to wilt in the field. The loads brought in by the tractor driver are dumped near the stack, and preferably without stopping. There should be room at the stack to accumulate at least eighteen or twenty loads while the stockman is milking. During the time he has to spare between milking, he puts the grass on the stack with a buckrake, paying particular attention to making firm sides, which are drawn in by at least a foot, and finishing with a level surface. This surface is sealed by adequate rolling with the tractor wheels to obtain a flat, slurried surface 5 feet high, 60 feet wide, and as long as necessary The area exposed while working must be related to the rate of filling. There should be very little surface or side waste if the work is well done with young material, which is not beyond the early flowering stage.

We like to use a 6 ft buckrake fitted with 3 ft 6 in. solid steel pointed tines for this work. Skill and experience enables a man to clear the loads rapidly, and to maintain an even, well compacted surface. The success of the whole operation depends on adequate consolidation which is easy on a level surface, but impossible on a rounded one.

Self-Feeding of Silage

Although many forms of barrier are used for self-feeding, on the whole we tend to prefer the convenience of a single well stretched wire at about 2 ft 9 in. high. This is usually only supported at the ends, but some men prefer to support it with one or two stakes driven into the face of the stack.

In Hampshire we seldom cover the surface with anything to keep out the air and the wet, because we find the wastage so small on the surface, that we do not think it is necessary.

Are these methods satisfactory?

The results can be assessed in two ways. First of all, many years of experience, with modifications from time to time as better machinery was developed, have enabled us to reduce the man hours required per acre of grass conserved from six to two hours. The cost of a days bulk feed for a cow has thus risen only slightly over the last fifteen to twenty years. The production of milk per man has increased fourfold in the same time, in spite of cutting the use of concentrates by one half.

This is not the place to go into lengthy discussion of the wastages which may occur with different methods of conservation and feeding. However it is necessary to emphasize that there are considerable differences of opinion about the methods of assessment of these losses. I can recall no work in this country, other than a little work at the Grassland Research Institute at Hurley, and some done by the I.C.I., which measures production from an area of land as a whole. Nearly all work measures conservation losses by assessing only the material which goes into storage, and what is taken out, and its analysis. A farmer is primarily concerned with what he can accomplish with his resources of land, labour and machinery as a whole. Any attempt to achieve perfection in one part, irrespective of the whole, may involve wastages elsewhere.

How can we make further improvements?

It becomes increasingly difficult to see further overall improvements in output per man and per acre. There is still room on most farms for increases in production from our grasses, mainly by the use of more fertilizers and better grazing methods. Theoretically there is room for improvement in the reduction of conservation losses, but the savings could be less than the cost.

Mechanically, a barrier is reached where increased speeds of cutting fill the trailer so fast that the trailer is only half loaded when it leaves the field. Finer chopping could help. We prefer to use more power to throw it back into the trailer and pack it tighter. Bigger trailers could be used on flat land, but may not be a solution on hills. A change in trailer design to give a lower centre of gravity and bigger wheels could help; but it is hard to visualize. Current trailer designs are good and a great improvement over what was available in the past.

Bigger loads on the buckrake to increase the speed of building the wedge are no answer to the problem, because they would require more manual work to pull the loads of grass apart. Skill in picking up and placing the load is the more important.

Cutting bigger crops in the field will only appear to fill a trailer faster, and may increase the haulage time because the loads have not settled in the trailers before they leave the field.

The easiest and most obvious benefits in crop conservation on an extensive scale can only come from the use of more power, and trouble free equipment in the field, combined with improved access roads and gateways between the field and the silo.

Contract Work

The methods which have been described in this paper have been based on relatively large self-contained units. As all the machinery and methods are highly mobile, and trouble free, there is no reason why the work should not be done equally well by a contractor using exactly the same equipment.

He could cut the grass for silage on three or four farms every day, leaving it at the silo for the farmer to store himself. This would give the essential sequence of grazing, as well as providing the winter feed. The in-line forage harvester and trailer, and division of work which occurs if there is room to store several loads of silage before it has to be put in the silo, gives complete flexibility to the method. It is in direct contrast to a team effort where the failure of one unit brings everyone to a halt.

Probably the only factor which delays wider use of these methods is the constant suggestion that they involve excessive waste, coupled with the recommendation that various methods of sealed and tower storage of grass are better. Whether or not they reduce waste, the capital cost of all the machinery and equipment which is involved must rule them out for most farmers.

My own experience during visits to cattle feeding areas in Canada, is that there is now far more storage in wedge stacks than in towers. Professor W. H. M. Morris of Purdue University writing in the February issue of 'Farm Buildings' states that the cheapest form of maize silage storage, *when wastage and feeding costs are included*, is in a wedge stack.

MECHANIZATION OF CATTLE FEEDING

POSSIBLE TRENDS IN THE MECHANIZED FEEDING OF CATTLE

by

JOHN M. MOFFITT *

Presented at the Annual Conference of the Institution on 11 May 1967 in London

Introduction

This extremely topical and very broad field of engineering is one which has interested me for some time. Having had practical experience of six years with a mechanized feeding system I can say with no fear of contradiction, that I have experienced most of the problems it is possible to encounter.

So this is a good opportunity for me as a farmer, as distinct from an engineer, to explain some of the problems as I see them and to throw out some thoughts for the future.

Perhaps I should first introduce myself as a Northumberland farmer, mainly interested in cattle breeding and milk production. Our two farms, Peepy and West New ham, total just over 1,000 acres, half of which is in arable crops, the remainder supporting 580 head of pedigree Friesians. The two dairy units comprise

1. 75 cow herd on self-feed silage;
2. 140 cow herd on a tower silo mechanized feeding system.

At present, on another farm, I am actively engaged in planning a third unit for 300 cows incorporating mechanized feeding through towers and housing the herd for the whole year.

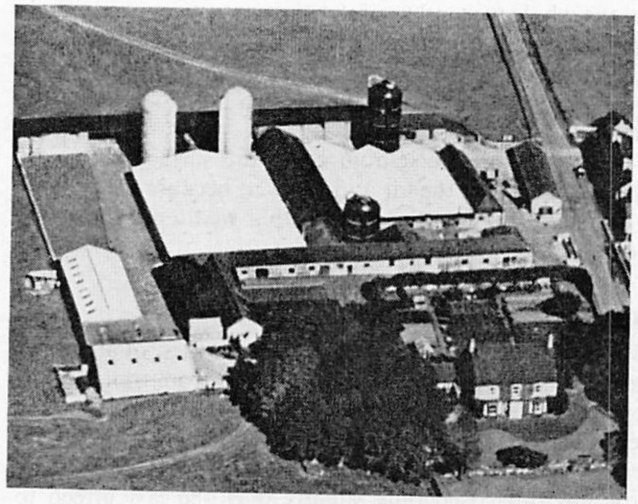
Prior to 1960, at Peepy, we had a completely conventional system of dairy farming, milking approximately 90 cows in five rather out-dated cowsheds. The stalls were too short and narrow for our Friesians and resulted in bruised hocks and damaged teats. All feeding and dung removal was carried out by hand.

In 1958 at a new farm at West Newham we installed a self-feed silage unit for 60 cows and followers and now after eight years of satisfaction with self-feed silage I would be the last person not to appreciate the simplicity and general efficiency of this system of dairy farming—a system which excludes the cowman from any mechanical operation in his daily routine. This system has been well proved and generally speaking, has satisfied the requirements of most dairy farmers.

Stimulated by a visit to Canada and Northern U.S.A. where labour is very scarce and expensive, I was brought face to face with the problem we are likely to encounter in British agriculture within the next dacade.

The decision to go 'towers' was not an easy one as there were few satisfactory installations in Britain and very few manufacturers with experience of this equipment in 1960.

Nevertheless, it was in the light of this experience that when we came to the re-planning of Peepy Farm, a much larger unit, we had to weigh the extra cost against an estimated 10% better utilization of crop in the storage, and rightly, I feel, came down on the side of towers and mechanized feeding.



Aerial View of 'Peepy'

Description of Peepy

As can be seen from the plan of Peepy we have one large cow shed to accommodate 120 cows in milk with loose straw yards and two 3-point 6-stall tandem milking parlours. This allows the herd to be split into two units, one man being responsible for each section. The dry cows and young stock are housed separately and looked after by the same dairy staff outside milking hours.

The increased number of young stock resulting in a larger herd, have to be retained until they reach the calving heifer stage where they are then either sold or brought in as replacements.

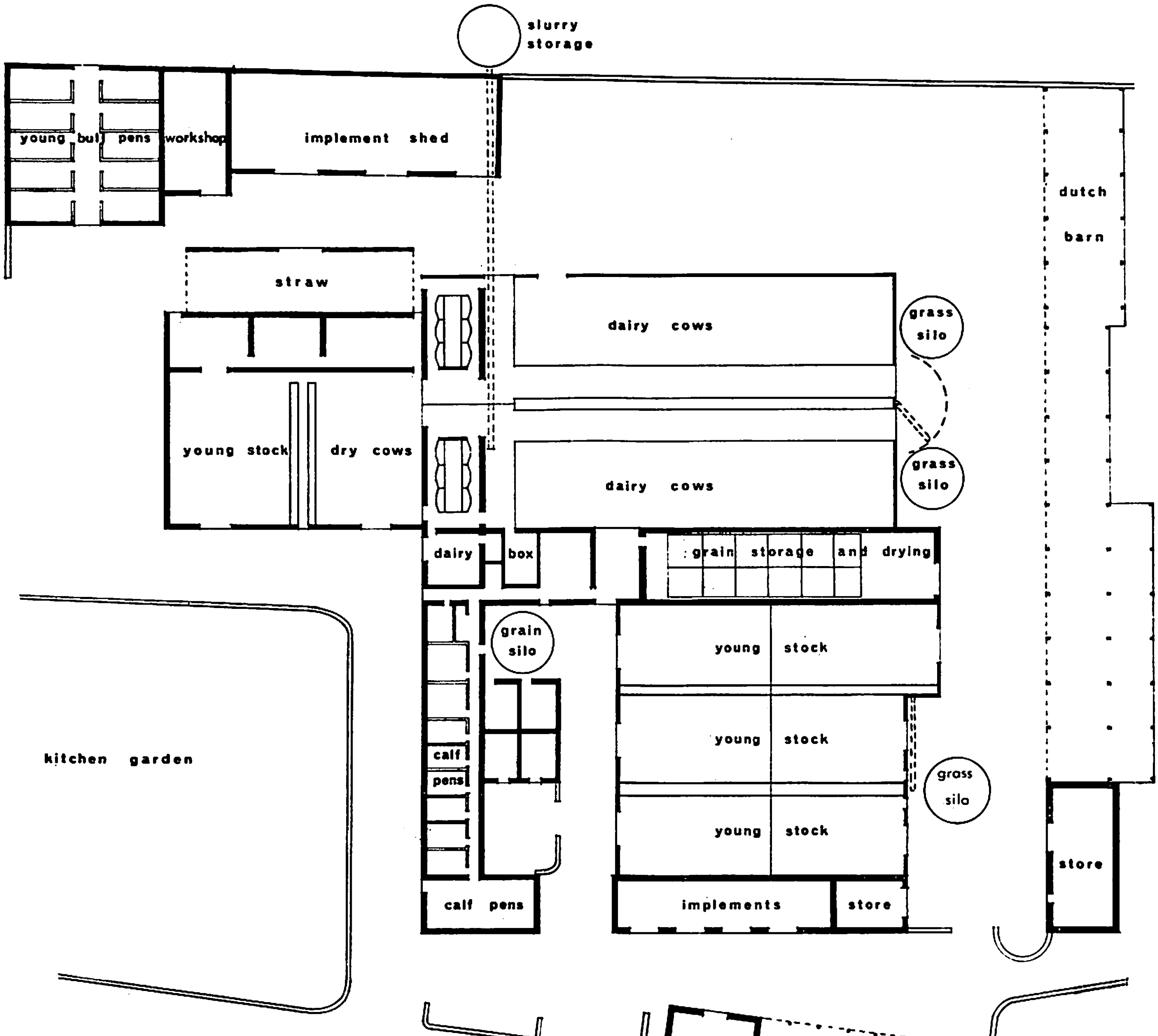
Problems of operating the System

(a) *Production of Grass*

Having spent a considerable amount of capital to achieve a reduction of labour and a more efficient method of dairying, it is vitally important that an equally efficient system of grass management is used, to make the best possible use of the towers.

We are, at Peepy, in a relatively low rainfall area with light soil but as we are able to irrigate more than 350 acres this allows us to make the maximum use of available land.

* Farmer



PEEPY FARM
STOCKSFIELD E. MOFFITT and SON

(b) *Field Operations*

The crop is cut and crimped at the stage where optimum yield and digestibility can be achieved, and it is necessary to cut two or three times in the season to obtain the yield per acre necessary for our winter requirements. We do, however, alternate the cutting with grazing so that we are able to provide the grazing herd with a clean fresh herbage.

Wilting of the crop takes, on average, 24 hours; but obviously this varies with weather conditions. The crop is then windrowed and picked up by a complete chop harvester and blown into 4 wheel self-unloading forage wagons. It is then brought to the farm and blown up into the tower by means of a tractor driven blower which has now filled 16 towers of forage and two towers of barley.

Because of the need for rapid filling, blower capacities could be increased. This would obviate the occasional blockage due to too rapid unloading. One of the new larger diameter blowers now on the market, should improve the filling immensely.

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POSSIBLE TRENDS IN THE MECHANIZED FEEDING OF CATTLE—*from previous page*

Our results show, and these are now confirmed by many other users, that the maximum dry matter of grass silage in the tower is achieved by wilting to about 40% d.m.

(*c*) *Filling the Tower*

The most essential factor in silo filling is to ensure that the crop is chopped short and even in length. If this is not done, the unloading and feeding equipment cannot work efficiently and one has to remember that one day of haste in the summer means one week of hell in the winter.

We have had the experience of three methods of carrying the material to the tower—

1. by trailer using the dump box.
2. by self-propelled forage wagons.
3. by 4-wheel self-emptying trailed wagons.

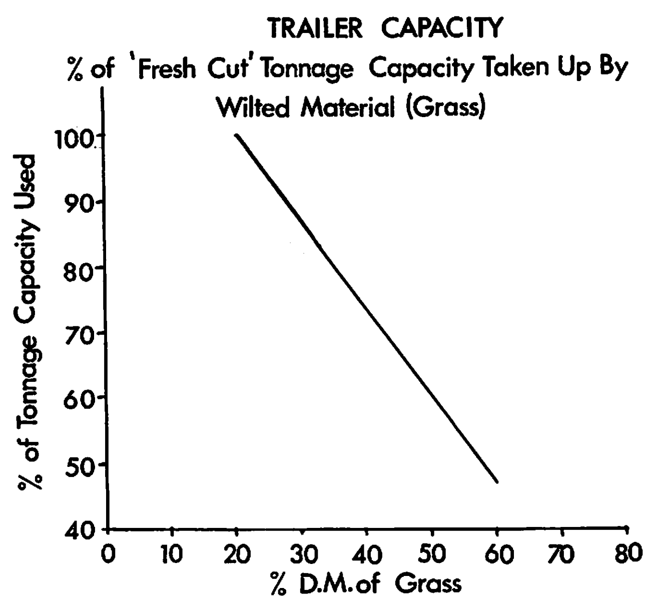


Fig. 1

I myself prefer the third system, i.e. a high powered tractor pulling the field chopper with the forage box coupled behind. We have found that two men with two forage boxes can adequately handle 20 acres per day and we are able to cut and complete two towers in two weeks' cutting and carting over 140 acres of grass, having a third man to cut and crimp the crop ahead.

When the tower is full it should be sealed off with a plastic sheet to prevent fermentation taking place and striking down. Care should be taken to tuck the edges well in and check daily for up to four days as settlement takes place.

There should be no excuse for making bad silage in a tower, unless weather conditions are particularly difficult. Bad silage can generally be put down to human failure and non-observance of these rules.

1. Fill tower with material between 35-50% dry matter content.
2. Fill at least 8 ft per day into the tower.
3. Level out if distribution is uneven.
4. Seal with a plastic or similar sheet if bad weather holds up operations.

The effects of wilting have a considerable influence on the total amount of grass to carry and chopping has the added advantage of increasing the carrying capacity of the trailers. It is possible in forage wagons of say, 7 ft width and 16 ft length to carry up to an acre of grass at 40-50% d.m. which reduces considerably the time loss in transit.

Figure 1 shows that with a trailer of a given volume the gross weight of a full load varies according to the d.m.% of the material. The effective content of the trailer as shown by the weight of d.m. carried does not vary to anything like the same extent.

Unwilted grass 1 acre=about 10 tons to haul for 2 tons of d.m.

Wilted to 40% d.m. 1 acre=about 5 tons to haul for 2 tons of d.m.

Figure 2 shows the percentage of tonnage capacity, in terms of equivalent green crop, which is taken up by the wilted crop in any given trailer. It is therefore possible to see how much a trailer capacity may be increased to bring the total weight of the load to that of the original load of met material, which it is known the tractor can handle.

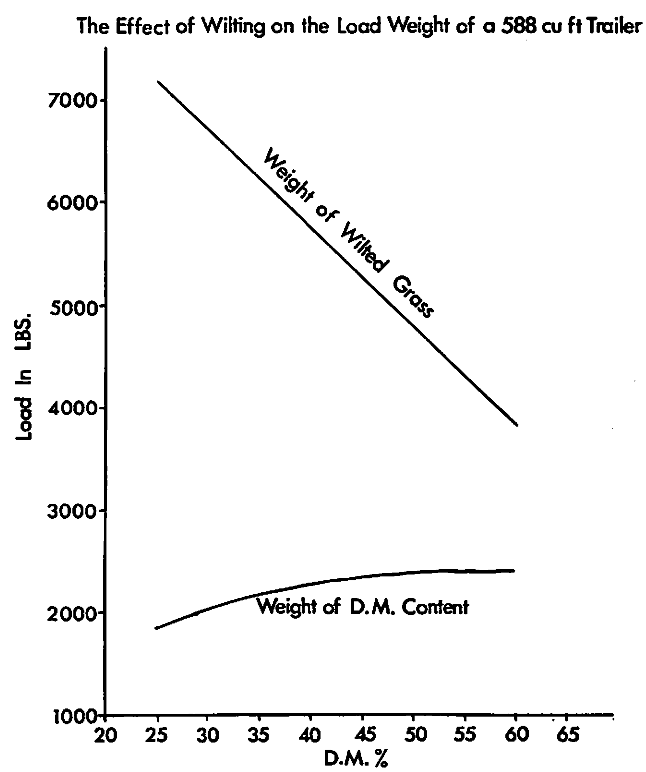


Fig. 2

Figure 3 illustrates the general improvement brought about by using the forage wagons in the reduction of man hours in filling the towers during the years 1962, 1963 and 1964. Performance was still further improved in 1965.

There are different methods of estimating the capacity of tyre silos and in consequence a wide range of tonnage

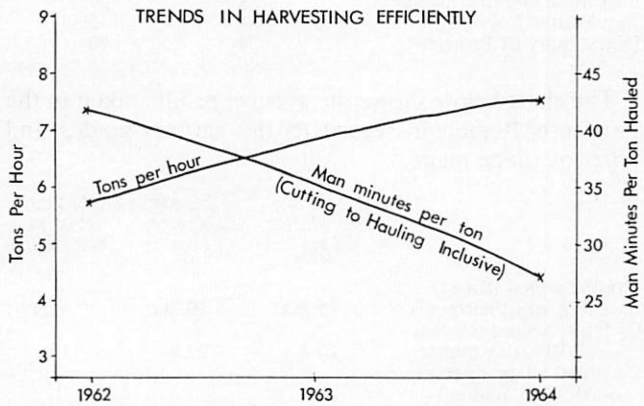


Fig. 3

figures is quoted for silos of a given size. This is reflected in the cost per ton of dry matter stored.

The main factors which influence tower silo capacity are:

1. Degree of wilting
2. Height ot settled silage
3. Length of material after chopping.

Feeding

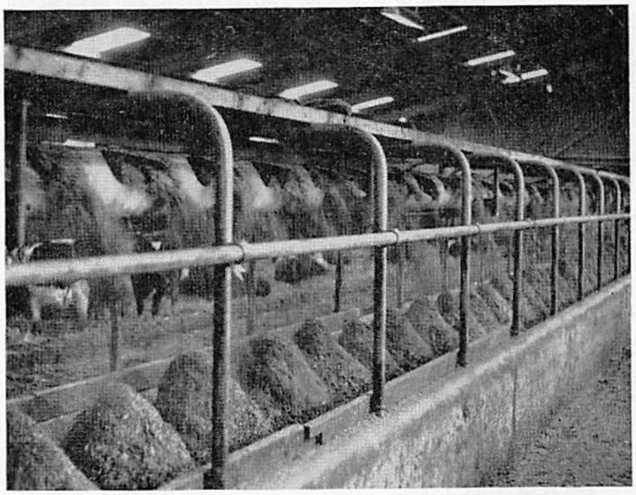
There is no doubt that the piece of machinery which causes most of the problems associated with mechanized feeding is the silage unloader. This has largely been due to the use of American machines designed primarily for use on maize silage, an entirely different product from our fine grass silage with low fibre content. It is pleasing to me to see British manufacturers improving on these American designs and the introduction of new types of unloaders, without blowers, should not only improve output, but the reliability of the machine. I must add here that it is necessary to use at least 3 in. of silage from the tower daily to avoid secondary fermentation taking place.

We have used augers exclusively for conveying the material to the animals and this is comparatively trouble free and can give a constant flow of silage evenly along the feed trough. The various makes available have similar outputs in relation to the diameter of the auger. The King size tube feeder which is in use at Peepy is just beginning to show signs of wear and we have now reversed it to give an extra few years of life.

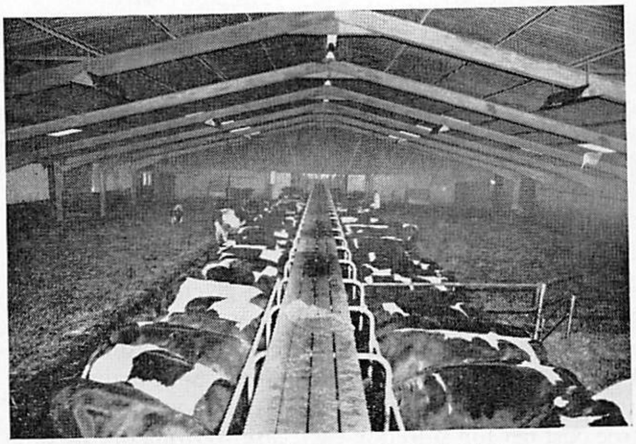
Augers are extremely noisy and I dislike them for that very reason. I think that manufacturers have overlooked this side of mechanized feeding, accepting all too readily the American equipment.

As bunk type feed troughs become more acceptable to dairy and beef producers in this country I should like to see long silent belt conveyors examined again in the light of past experience, and at the same time, high frequency vibrating conveyors could well play an important part in conveying material to a given point. However, it is at least refreshing to see that at last chain and flight conveyors can now be made to operate efficiently with little maintenance requirement.

As larger and larger numbers of animals are housed together, corresponding increases in output will be



Efficient Distribution of food in Manger by Tube Feeder



Cows Feeding © Photograph H. G. Clarke

required from these machines. We shall probably require up to 10 tons per hour delivered to several feeding bunkers from any one tower.

However, the greatest requirement is reliability and efficiency of work. We can compare the early motor car with its own peculiarities, with the present day feeding systems, and I hope that the reliability of the modern car can be equalled in the next few years. Remember, that the task of feeding livestock is that of a stockman, not a mechanic, and not until this reliability is a reality will mechanized feeding receive universal acceptance.

In 1960 the design of a unit for 120 cows-in-milk and 20 dry cows, was a formidable undertaking, and partly

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POSSIBLE TRENDS IN THE MECHANIZED FEEDING OF CATTLE—*from previous page*

Chopping and Loading into forage wagon

because we were bound to be guinea pigs in this sort of enterprise we had the advantage of being able to obtain a package deal for all the equipment, which compares favourably with prices obtaining today.

2 galvanised steel towers 20 ft × 50 ft	4,000	
Top Unloader	550	
120 ft of Tube Feeder	500	
Dump Box	450	
Blower	180	
Forage Chopper..	700	
		6,380
Building—136 ft × 85 ft complete ..	4,150	
Building work, including twin parlours, dairy etc.	6,860	
	11,010	
Less 30% Grant Aid	3,687	
		7,373
		£13,753

Tremendous assistance has been given by A.L.S. and N.A.A.S. carrying out a full time work-study operation over a two year period on Peepy and West Newham Farms, trying to co-relate the differences in management and practice and getting down to the important factor of true cost per ton stored in each case. Writing off the total cost in both cases over a ten year period, i.e. the tower silos, field and farm machinery and the main cow yard at Peepy and the self-feed area, bedded area, field equipment at West Newham, depreciating all this equipment etc., we arrived at a cost per ton of dry matter; surprisingly enough the cost did not differ very much—for Peepy £3 15s. 0d. and for West Newham £3 7s. 0d.

Experience

We have now emptied 16 towers and thanks to the efficient services of N.A.A.S. Chemists, 1,546 samples have been taken during filling to give an accurate analysis not only of dry matter but the mean composition of the material. A similar number of samples, taken during the unloading in winter, has given an accurate account of the losses which have taken place.

Figures received from N.A.A.S. Chemists 23rd January 1967 are:—

% dry matter basis

	Green Matter put into towers	*Silage brought out of towers*
No. of samples taken 1961 to 1966	1546	1207
No. of sets of tests	19	19
Dry Matter %	41.6	41.0
Crude Protein %	11.8	11.9
Crude Fibre %	29.66	31.31
Digestible Crude Protein % ..	8.4	8.3
Starch Equivalent %	46.7	44.0
Digestible Organic Matter % ..	56.1	54.9
Dry Matter Loss	—	5.3
Digestibility of Protein % ..	71	70

The chart below shows the average results taken in the Northern Region in regard to the various grades and types of silage made.

	Dry Matter Loss %	*Starch Equivalent Loss* %	*Loss of Protein Digestibility* %
Double wilted (tower) —40% dry matterLL	5.3LL	10.7LL	1LL
Ordinary wilted (clamp) —25-30% dry matter	10.4	22.4	15
Unwilted silage (clamp) —20% dry matter— well made	16.7	33.3	12
Unwilted silage (clamp) —20% dry matter— badly made	22.8	44.2	15
All unwilted silage (clamp) —20% dry matter	19.8	3.90	13
All clamp silage —23% dry matter	15.3	30.8	14
All vacuum silage —23% dry matter	14.5	29.2	0
All silage made with sodium metabisulphite —23% dry matter	10.3	20.6	0

—Peepy figures make up the major portion of these results.

What has this achieved?

1. A reduction of one-third in the labour force, i.e. 2 men less involved with the herd.
2. A 30% increase in herd numbers.
3. A simple system of feeding good quality high dry matter silage.
4. A consistently reliable food. (Over 6 years the average loss of starch equivalent has been only 6% with other losses negligible.)
5. An initial loss of milk due to severe changes. (Firstly in the milking bail, secondly the introduction to the new parlours and in particular the difficulty we experienced with older cows which because of their high breeding value we were not able to cull.)
6. A greater profit margin—taking into account depreciation of buildings, machinery etc.

Economics

One frequently hears it said that mechanical feeding can be justified on a 70 cow milking herd and certainly there are figures to prove that it is so. I would, however, be dubious about putting up a new unit for less than 100 cows not just because of the high cost and return on capital but because I believe 100 cows should be the minimum economic unit of the future.

Under the investigation carried out in 1964 the graph in Figure 4 indicates:

1. that the breakeven between tower systems and unwilted silage self-feed system occurs at the 50-60 cow unit stage;

2. that the breakeven between the tower and wilted self feed system occurs higher up the scale of enterprise in the region of 80 cow units.

Food output per acre has risen greatly during the past five years and further exploitation is well within our present limits. Provided the British farmer is allowed to produce a major part of our food requirements the outlook for mechanized feeding is extremely bright. Remember that 99.5% of food for our livestock is still hand fed.

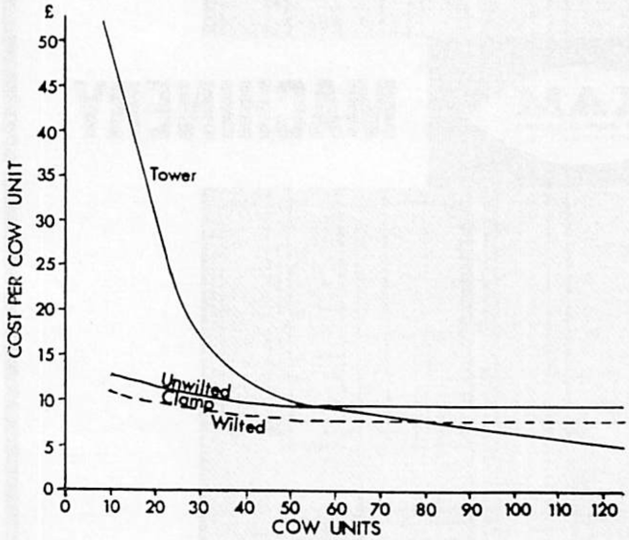


Fig. 4

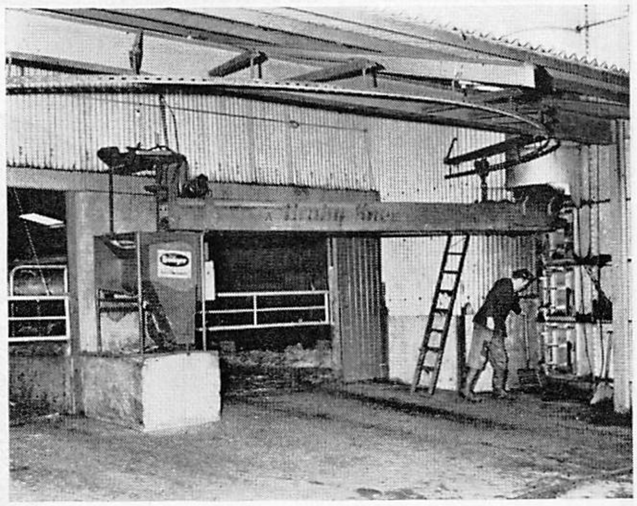
I have so far kept my paper to the feeding of the dairy cow for my experience of feeding beef cattle is limited. However, as I see it the problems are identical. All ruminants require a good quality food to give maximum live weight gain or high milk production, and most of this can come from conserved grass or forage in the tower.

Cereals can be metered into the system at the input end and the storage of high moisture grain from a sealed tower can be an important part of any layout.

My own experience is one of extreme satisfaction, not only in overcoming the need for artificial drying but in providing the animals with a more palatable diet.

Design

Perhaps the most important aspect of any new enterprise is the design and it is not a bit of good an architect planning a layout if the food is to be conveyed over vast distances; convenience of storage towers to trough should be a first priority. At the same time, if there are fundamental changes in design of layout, manufacturers should accept this challenge and find a practical answer to any particular problem.



Cross Conveyor from Tower to Feeder
© Photograph John Topham Ltd.

I should just touch on the controversial subject of tower dimensions as obviously there are economic limits in both height and base diameter. The very large tower has the advantage of cheapness of storage but with it comes a multitude of problems. It is no use putting up vertical storage if one cannot conserve the grass efficiently and one must put in a minimum of 8 ft of grass a day to avoid fermentation, and it should be remembered that a 26 ft diameter tower is almost double the capacity of a 20 ft tower.

The answer must lie in the size of the enterprise and I am doubtful if I would ever go above 24 ft in diameter using the maximum height.

Conclusions

1. That a silo is most effectively used when it contains the maximum amount of dry matter.
2. The optimum average dry matter for tower silage is 40% but in practice there will be a varying amount of material below this level with the consequent danger of producing effluent.
3. Under-wilting produces effluent with the consequent lowering of conservation efficiency.
4. Over-wilting limits capacity and is therefore expensive and in addition dryer material gives trouble with unloaders and if very dry, overheating may occur.
5. It is best to aim at a 40% to 45% dry matter level.
6. The height of settled silage directly influences the density and consequently the tonnage contained in a tower silo. Therefore towers should be as high as possible.
7. The rate of filling is critical and should not be less than eight feet per day to avoid heating. Similarly the rate of unloading should not be less than 3 inches per day to avoid spoilage.
8. The greater efficiency of conservation in the tower

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(*Conference continued on page 107*)

MECHANIZATION OF CATTLE FEEDING

ENGINEERING PROBLEMS IN CATTLE FEEDING WITH SPECIAL REFERENCE TO TOWER SILO INSTALLATIONS

by

J. H. KNEE, AMI AGR E*

Presented at the Annual Conference of the Institution on 11 May 1967 in London

Introduction

I want to start this paper by contradicting the title. The title presupposes, I feel, that the problems associated with the mechanized feeding of livestock, with particular reference to tower silos, are difficult. They can however, be made difficult if the fundamental knowledge which we in the silo machinery business have learned since the early 60's, is ignored. There is still a tremendous amount to be learned about the handling of short chop silage, but I feel strongly that the bread-and-butter farmer need not run into difficulties providing he is prepared to take advice from someone who knows his business. I know however, only too well how difficult it is for a prospective silo owner to get the facts he wants before he takes the plunge. Even his best friends often will not tell him that he has bought a 'bluey'.

We are all aware that there have been difficulties and I will be the first to admit this. I would also be the first to admit that we are not completely out of the wood yet; but I know that all the firms engaged in this particular business now know the fundamental key.

That is that the handling properties of maize silage are entirely different from grass—in particular lush green British grass.

You have no doubt all heard of people who have tried whole crop barley say how much better their silo machinery works with this material; this is because like maize it has a so much better flow characteristic. However, good milk and beef producing grass is the major asset of the majority of our farms and it is grass that we must concentrate on for the purpose of mechanization. An easier crop to handle must be a bonus and not a standard.

Wilting

The first job, which is not mechanized, is to wilt the grass. This is necessary for a variety of reasons, the least of which is to help the future handling of the material. The silo is a food container and not a water tank. With wet silage there are much greater pressures and consequently higher seepage and maintenance problems on the silo (Fig. 1).

The silo on the left is unhappy because he was filled at eighty per cent moisture, and therefore for every twenty tons of dry matter stored he has to support a hundred tons of total weight.

The silo on the right is happy because at fifty per cent moisture for every twenty tons of dry matter stored, he only has to support forty tons.

The one in the middle is a happy average.

Another good reason for wilting is the amount of work and therefore money, used in carting from the field to the silo. A four ton wagon or trailer does not mind how you make up the four tons; it can be all water, or all dry matter (Fig. 2). In the top case we have a wagon loaded with, say, 9,000 pounds of grass at 80 per cent moisture so that there is only some 1,800 pounds of dry matter being carted. At the other extreme the wagon still carries 9,000 pounds but this time the load is at 50 per cent

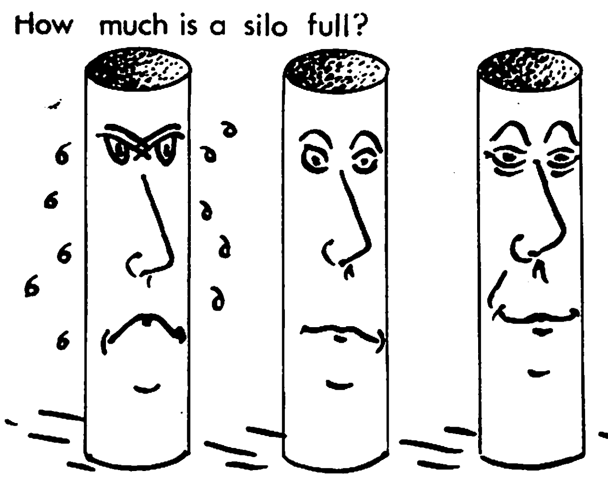

Fig. 1

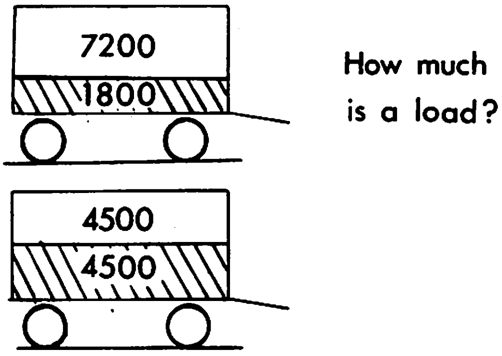

Fig. 2

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* Knee Agricultural Machinery Ltd.

ENGINEERING PROBLEMS IN CATTLE FEEDING WITH SPECIAL REFERENCE TO TOWER SILO INSTALLATIONS—*from previous page*

moisture so that 4,500 pounds of dry matter is carted—or 2½ times the actual pay load of the 80 per cent moisture loaded wagon.

Chopping

Short chop is also necessary in order to give the material some flow characteristic and also in allowing the silage to settle in the silo more readily, thus increasing capacity and excluding rapidly the arch enemy of correct fermentation—oxygen.

Of all the different models of full chop machines on the market there are only two basic types—the fly wheel and the cylinder. Both types usually have six cutter blades although some of the larger machines run to eight. Both types are capable of carrying out their function perfectly if the knives are kept sharp and properly set up, but they all need a good powerful tractor if they are to give their best. The cylinder type is gaining preference in this country, if only because by the nature of its design, the manufacturers can incorporate an 'in situ' knife sharpener, thus eliminating the need to replace the knives when they become blunt or chipped. Manufacturers of fly wheel choppers however, have not been slow in realizing the importance of this point and many now offer knife sharpeners. An important point to watch here, however, is that once the knives have been subjected to the stone, the resetting of the knife edge back to the shear bar must be a simple operation, otherwise this part of the job is not done and the sharpening of the knives is worse than useless.

Mechanical failures on full chop machines are mostly caused by metal or other debris getting conveyed into the chopping chamber. A fly wheel type chopper has the advantage here over the cylinder type due to the high momentum generated by the heavy fly wheel. Breakage occurs when the cutter decelerates and very expensive noises can be made when the chopping mechanism comes to an abrupt halt. A good heavy roller applied to the land in early spring is one safeguard: another is to instruct all maintenance staff to check that every time a field adjustment is made to any machine, tools are carefully counted back into the tool box.

Moving

The choice of getting the chopped material from the field to the silo can be either by four wheel self-unloading forage wagons, or ordinary two wheel tipping trailers using a self-unloading dump box at the blower.

The case for forage wagons as I see it is as follows.

The average throughput of a forage full chop harvester can be assumed at 16 tons per hour. A six ton wagon filled to its cubic capacity can hold approximately four tons of wilted material and it will therefore take 15 minutes to fill. Allowing an average haul time of six minutes both ways, at 20 tons per hour the blower will handle this amount in 12 minutes. One wagon will therefore be back in the field in 24 minutes; during this time the second wagon will have been filled in 15 minutes and the chopper will have been idle for nine minutes. This lost time can only be overcome by employing three wagons at a capital cost of between £2,000 and £2,400, or by drastically improving blower performance. A modern forage blower working with a powerful tractor under ideal conditions can handle wilted chopped material at 30 tons per hour Thus the waiting time at the silo under good conditions, can be reduced to eight minutes and overall turn-round time for a wagon will be 20 minutes.

So even by increasing blower output by 50%, the waiting time in the field is still appreciable at five minutes per load.

If forage wagons are to be used, there is a case for using the largest capacity wagons available, bearing in mind all the difficulties which may be encountered in physically moving a heavy load. For example, in the case of a 12 ton wagon holding eight tons of material, using the same figures as before, the chopper waiting time is reduced to six minutes. Conversely, with a smaller wagon this time is increased.

Using a dump box it is cheaper to obtain the vital third transport. Assuming the same performance figures as already quoted, a three ton capacity trailer will hold two tons of wilted material and will take 7½ minutes to fill with the same hauling time and same blower output; the time from and to the field will be 18 minutes and during this time the chopper can fill two trailers in 15 minutes showing a theoretical waiting time of three minutes only. Capital cost, using new tipping trailers and silage sides plus one dump box is about £1,650. Of course there are many variables which come into any exercise such as the one outlined above, but I feel that the point is made that in practice either method will give the same output as long as three moving units are available.

Blowing

Forage blowers in this country have aligned themselves into two distinct camps. There are those of the American type using nine-inch diameter pipes and the German types using larger diameters. The nine-inch pipe blowers are virtually identical to the blowers used in the United States for filling silos, whereas the German blowers, having the larger diameters, are derived from machines used for filling German hay barns.

Of the 27 manufacturers of forage blowers listed in America in 1965. 20 used nine-inch diameter pipes, two used eight-inch pipes, two used seven-inch pipes, two used six inch pipes and one used 14-inch pipes. The recommended horse power on American standards is between 30 and 40 and in this country it has been found that higher horse powers are normally needed.

Again diameters of the impeller vary considerably from 24 inches up to 56 inches. The majority of diameters however, are 48 inches but the 54-inch is gaining preference. At this larger diameter, however, the horse power requirement of the tractor is creeping up, but so also is the throughput.

The tip speed of a 48-inch diameter fan rotating at 600 rev/min will be 126 ft/s, whereas a 54-inch diameter fan

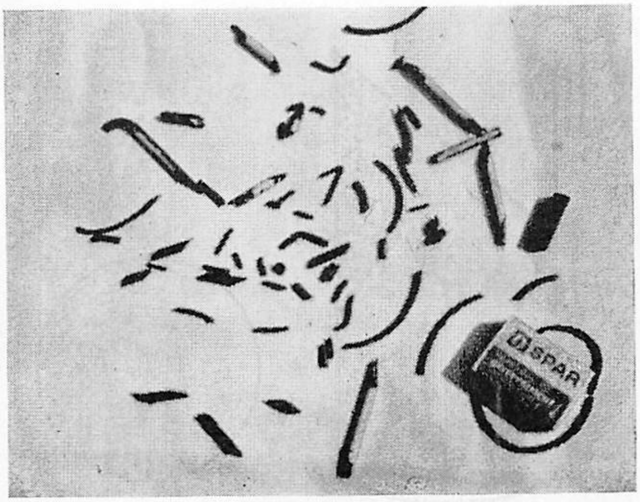

Fig. 3

rotating at the same speed will have a tip speed of 141 ft/s. This is an increase of 12 per cent for any given revolutions for the larger diameter. Unfortunately we cannot go on increasing the diameter in order to increase the tip speed of the fan unduly because of the horse power requirement at the p.t.o.

Gum produced from some grasses can cause undue frictional loads on forage blowers and when this occurs the only way to cure it is to pass water through the fan itself and the easiest way to do this is to attach a hose pipe to the outer band of the blower so that water can be dribbled into the machine all the time it is working. It has been found that by allowing the tap to run at the rate of one gallon per minute, the output of the blower is increased by at least 15 per cent. This amount of water does no real harm to the dry matter content of the material, for even if the tap had to be left running for the whole of the filling operation of the silo at the suggested rate, then the moisture content of the full silo would be increased by less than a quarter of one per cent.

Owing to the fact that all forage blowers are in fact throwers there should be no bends incorporated in the blower pipe itself as the grass is not itself travelling in a column of air, and any restriction will slow down the movement of the grass immediately, which can of course cause blocking. It has even been found that dents in the pipe will greatly reduce the throughput owing to the fact that the grass when projected up the pipe will start to bounce from side to side and thereby increase the frictional resistance. Ideally the grass should be blown into the silo by as simple a swan neck as possible at the base of the roof of the silo. The further it has to travel in a horizontal plane the more back pressure will be built up in the vertical piping with a corresponding increase in the chance of a blockage.

Fitting a high-powered magnet on the blower is a fairly reliable insurance against short pieces of dangerous wire being eaten by the cows during the winter. This is particularly important on new installations and where the fields have not been used for haymaking and silage purposes for some years. A sample of material collected from such a magnet is shown in figure 3.

Spreading

Automatic spreaders are available for fitting on the end of the swan neck or filler pipe and they are basically of two different types. One type is where the grass is blown onto the centre of a revolving plate and by adjusting the angle of this moving plate, either up or down depending on the diameter of the silo, the grass can be deposited round the outside diameter of the silo. One of the reasons for doing this can be seen from figure 4. Height means compression and compression in turn, means greater

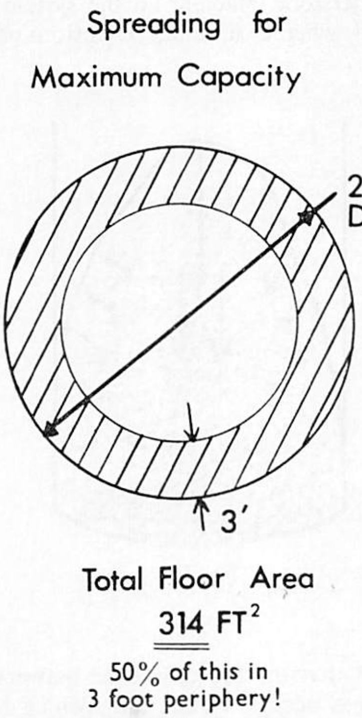

Fig. 4

capacity; one should therefore get the maximum capacity on the largest area.

The other type of spreader makes use of a moving hood fitted to the top of the vertical piping and by means of an electric motor or hand operated unit attached to the top of the blower itself the whole pipe is allowed to oscillate left and right, and by a system of return springs and a wire, the end hood moves in and out. Combining these two movements, a circular action is obtained which again throws the material to the wall.

Although all these spreaders are a great asset, they should never be looked upon as the perfect answer. Many variables creep into their correct functioning. The main difficulty is that wherever the plate or hood is directed the grass coming from it is subjected to strong up-currents of air trying to get out of the silo.

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ENGINEERING PROBLEMS IN CATTLE FEEDING WITH SPECIAL REFERENCE TO TOWER SILO INSTALLATIONS—*from previous page*

There is nothing worse, however, than being faced late in the evening after a hard day's work with a great mound of silage coning up in the centre of the silo which has to be levelled off. If it is not levelled or concaved, then the silage will tend to pull away from the silo wall with a good chance of soilage occurring between the silo and the silage (Fig. 5).

Top unloaders perform at their best if the density of the silage is constant all round the circumference. A silo which has consistently settled at an angle will present different densities on its open face when being unloaded (Fig. 6).

Unloading

The least understood machine in the system is the silo unloader itself, whether it be top or bottom unloading. It is in this field that the big difference between handling maize and grass occurs. Grass gum, which has already been referred to, is of major significance. Of over a hundred top unloader users who were circulated recently to try and find some common denominator which caused gumming, no true picture emerged except that there seems to be a critical moisture content which allows more gumming to occur than any other and on the whole it would seem that wetter material, i.e. 35% to 40% dry matter, is less prevalent than 55% dry matter material, although unfortunately this cannot be stated as a definite fact. Some grasses have more pectin than others, notably rye grasses, but I feel that a lot more technical research needs to take place on this aspect. I have already referred to gumming on the blower used for filling the silo and where this has occurred the red light should be up for the farmer to watch for this point when he is unloading. The blower fan on the top unloader being so much smaller than the forage blower, any deposit will have more effect in slowing the blower and causing lack of correct throw-out through the silo door. This in turn means that some of the silage falls back inside the silo and on subsequent rotations of the unloader auger this pile is collected in a great mass and causes a blower blockage.

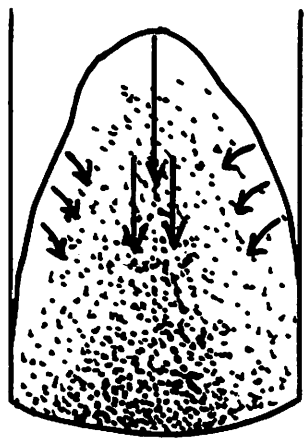

Fig. 5

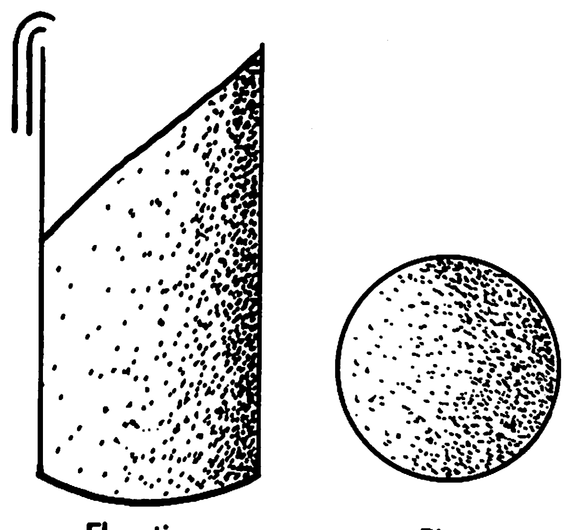

Fig. 6

There are two types of top unloader currently available. There is the conventional type, having an auger or augers drawing material to the centre, where it is collected into a blower to be thrown out of an open door, thence to fall down the outside chute. The capacity of this type is governed by the size of the blower itself which in turn is limited by horse power available.

The performance of the auger or augers, is not critical since any top unloader can be let into work to the point where any fan can be blocked by the auger output.

A different approach is by the use of an internal chute formed inside the silo, either in the centre where it is made by pulling a bullet up the middle as the silo is filled, or by special folding metal doors situated just inside the silo, usually adjacent to the existing doors and outside the chute. The cutting out and discharge of these types is usually by auger or chain and cutters. No blower being required, the output is greater, but the cost is higher.

Bottom unloaders come in two different types. There is either the sweeping arm chain and cutter or the new type recently seen over here and imported from Germany where the silo itself is lifted on stilts and a chain and cutter revolve round the inside conical base of the raised silo. So far there are no bottom unloaders which can be fitted into any silo, they have to be made specially for their own silos.

The farmers' decisions between these two main types, lies between the question of whether it is preferable to feed 'first in and last out', or 'last in and first out'.

Siting and Feeding

Siting of the silo in relationship to the method of filling, future expansion and the subsequent feeding operation, must be looked at right from the start, because unless these points are watched carefully extra expense may be incurred. Moreover, the difficulties which may subsequently appear could be eliminated from the start instead of having to be lived with for the next twenty or thirty years. For example, it should be decided as to whether the farmer is going to use forage wagons or a dump box to fill the silo, bearing in mind that most machines on the market are designed to discharge to the left, in accordance with the way they are normally produced. There have been cases where silos have been so erected that when the subsequent filling of the silos was discussed it was virtually impossible to fill the silos.

Likewise the type and make of feeder should be considered at this early planning stage, depending upon whether the feeder will be of the progressive type or the instantaneous, these being the two main types available. As the name suggests, the *instantaneous* feeder is of the type where some food is deposited in the manger right along its whole length, virtually as soon as the top unloader starts to work. The *progressive* type allows the food to be deposited in the manger progressively from the beginning of the manger to the end. If animals are to be in attendance at the manger right from the start of the feeding operation then the instantaneous feeder type is by far the best, but whereas in many cases the cattle are held in a holding area prior to milking and the mangers are filled during this period, then a progressive feeder is perfectly adequate and is usually cheaper.

There are very few installations where the silage can be deposited directly from the silo straight into the beginning of the feeder and normally some form of primary conveyors have to be supplied. These primary conveyors are relatively expensive and they should therefore be kept as short and as uncomplicated as possible, There is of course no absolute need to have a feeder at all but a forage wagon or forage dump box with a cross conveyor can quite readily be used to fill the manger. However, it must be decided early that this is what is going to take place so that generous access and availability to the manger can be obtained by the forage wagon and so that the forage wagon can be filled by the silo machinery. The wagon under these circumstances is going to be filled during the winter months and it is advisable to make some provision for protecting the wagon from the wind and rain during its filling operation otherwise the yard is going to get nearly as much silage as the manger.

Silos

Although not strictly within the limits of this paper, the choice of silo has some bearing on the subsequent operation of silo machinery. We are not concerned with the material from which the silo is made, but on the size and design of the silo itself. Ideally, for a silo to be unloaded with a conventional unloader, by which I mean a top unloader using a blower, there should be a slit all the way down the silo at the unloading side. As this is obviously impossible, the aim must be to have the openings as large as possible, with distance between doors reduced to a minimum. The filler hole should be low on the roof, so that the blower can discharge into the silo directly after it has finished its vertical lift. This position also allows the unloader to be above the stream of grass and away from interference with spreaders when the silo is being filled and the unloader is in its summer position.

The ideal size of a silo is one which will feed 100 animals 25 lb of dry matter for a six month period. This capacity is obtained with a 22 ft—60 ft silo which is neither too wide for proper loading and unloading nor too high for rapid filling and will not have extremely high density material at the bottom which drastically cuts down the top unloader performance. When buying a silo one must not just go by the capital cost per cubic foot but think of the machinery which will be needed to service it.

Summary

Mechanization as opposed to automation of cattle feeding is here. At the moment it is considered expensive, but a few years ago it was considered a luxury few could afford. Mechanization of poultry feeding has been accepted for a decade or so and surely if we look back to the early post-war period nobody then would have contemplated the revolution that would shortly take place. Chicken meat was then a luxury, but now it is well within the purse of everyone. Pig feeding is also well mechanized and will become even more so.

Dairy and beef farmers were left in the doldrums until the grass, which is their prime feed source, could be made to move mechanically by storing it vertically and chopping it short. I know that the cow herself is a good reliable mechanical feeder, but I liken her working away at the self-feed silage face, to a man condemned to living practically off soup with an obstruction in the way which makes it difficult to get at. For my part I would prefer a more concentrated food presented in the easiest possible way to eat.

If the number of words now appearing every week and every month in our trade journals are anything to go by, as I am certain they are, this whole aspect of high dry matter silage and mechanized feeding has fired the imagination of all thinking farmers. With land getting dearer, more scarce and, to say nothing of the farm labour problem, more and more silos are bound to be built in the years ahead. Just how quickly depends to a great extent on those firms who are responsible for silo machinery, for it is on the reliability and correct working of the machinery that so much depends.

MECHANIZATION OF CATTLE FEEDING

TOWER SILOS FOR GRASS CONSERVATION

by

V. H. BEYNON*

Presented at the Annual Conference of the Institution on 11 May 1967 in London

INTRODUCTION

In recent years the word 'productivity' has been belaboured more than most and reference has been made repeatedly to the need for higher productivity in the United Kingdom as the means of solving many of our economic problems. Sector productivity estimates are being widely used to highlight relative performances and farming is always included in these exercises. The data for the farming industry show a proud record of improvement in the post-war period, and achievements in the 60's have been the envy of most other industries. It is tempting for farmers to claim for themselves full credit for these worthy performances, but it must be appreciated that varieties of seeds, the greater use of more effective fertilizers, higher yielding livestock, better appreciation of nutritional needs, as well as a whole array of chemicals and antibiotics have made a tremendous impact on crop and livestock production. In addition, with the appearance of a host of labour saving devices including the modern tractor and its allied equipment, farmers have been able to cope with the exodus of labour to other industries without sacrificing production. As far as labour productivity is concerned the trend with crops has been particularly impressive, but livestock production has not exhibited the same degree of improvement. It is true that improved milking facilities have resulted in considerably reduced labour requirements in dairying, but the feeding of livestock has proved a most intractable problem, and has claimed far too much expensive hand labour. Self-feeding of silage does, of course, represent a step in the right direction but silage itself is not accepted by all farmers.

To date then, the feeding of livestock in the U.K. is, by and large, an ardous task making heavy demands on manual labour. But repeated reminders that farmers in the United States have largely solved the problem and are able to feed large numbers of livestock with the minimum use of labour have not gone unheeded. Growing numbers of British farmers are introducing equipment which will not only make labour far more productive in feeding stock but also, they hope, help to improve the quality of the final product. As with most innovations, technical difficulties are being encountered and the quest for perfection continues, but there is a real danger that imperfections, coupled with the high costs of some of the new equipment, may dissuade many from even considering the investment of capital. Reticent attitudes to capital innovations are also conditioned by the long era of a relatively cheap and abundant supply of labour in the United Kingdom. This era is now past and serious consideration must be given to the possibilities of substituting capital for labour. This substitution is taking place all the time and already in the U.K. the capital input is greater than the input of labour—we have in fact one of the most capital intensive farming industries in the world. This trend will go on provided the further application of capital continues to be worthwhile. This is dependent on the relative cost of labour and capital.

A number of developments is tending to make labour relatively more expensive. For instance the increased bargining power acquired by the trade unions has forced up wage rates, reduced the normal number of hours in a working week and at the same time increased the number of hours of expensive overtime. The trade unions have been assisted in their efforts by full employment policies which have tended to create a situation wherein too few workers are chasing too many jobs. Fiscal policy also in recent years has often encouraged employers to retain more employees than absolutely necessary since after allowing for the impact of income tax, the cost of marginal amounts of labour has been very low. All these factors have tended to make labour more expensive and perhaps less reliable. Farming in particular suffers the further disadvantage that the more enterprising and adventurous leave the industry unless they are offered earnings and conditions of employment similar to those in other industries.

The cost of capital has also changed. It is tempting to claim that the changes have been very small since the bank rate has not varied greatly. This would be an oversimplification because due allowance must be made not only for interest rates but also for the fall in the value of money. In real terms therefore the cost of borrowing capital may have changed significantly. One must likewise remember that new technology incorporated in machinery and equipment is making capital far more productive. There is little doubt that the increasing cost of labour and the attraction of capital will encourage the continued introduction of more and better capital investment in the industry. The growing number of tower silos appearing on the landscape of this country is a manifestation of this development. There is a danger though that this may be taking place without a full and thorough examination of the costs of the various inputs and of their effect on output. The purpose of this paper is to emphasize the need for taking this elementary precaution when considering the introduction of tower silos for grass conservation. There is a tendency at the moment to regard the

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tower silo as the panacea for all the difficulties experienced in the production and utilization of grass. Is this justified simply on the basis of sporadic but perhaps over generous claims made for it? Naturally in the early stages of its introduction to British farming there is a dearth of reliable data for assessing its impact but every effort should be made to acquire more comprehensive data before involving farmers in heavy capital investment. Here responsibility rests not only on the shoulders of farmers and advisers but also manufacturers of this equipment.

As part of an effort to provide reliable information a study was undertaken by Exeter University of as many farmers as possible in the counties of Cornwall, Devon and Dorset who had invested in tower silos for grass conservation. The numbers were small but included all the different types of tower silos with the vitreous enamel type being most prominent. Obviously the decision to invest in one or other of the different types of tower silos is tied up with a number of factors. These include the cost of the towers themselves as well as the cost of the allied equipment, the expected life of the tower, maintenance costs, the effect on labour, on wastage and on the quality of the product. Each of these factors is discussed briefly.

TABLE 1

Net Capital Costs of Silage Tower and Allied Equipment

(capacity approx. 17,000 cubic feet and based on January 1967 price)

Type of Tower	*Galvanised*	*Concrete Stave*	*Vitreous Enamel*		*Glass Fibre*
			Top Unloading	*Bottom Unloading*	*Top Unloading*
	£	£	£	£	£
Tower Silo	2,100	1,729	2,373	2,671	2,730
Allied Equipment:					
Loading & Unloading	1,950	1,950	1,950	1,965	2,240
Harvesting	2,050	2,050	2,050	2,050	2,050
Total	6,100	5,729	6,373	6,686	7,020

BUDGETING DATA REQUIRED

Capital

It is extremely important that salesmen should supply farmers with comprehensive data on the costs of the entire tower silage system. At present discussion is often restricted in the initial stages merely to the costs of the tower itself. These costs, after allowing for grants, accounts for less than half the net cost of all the equipment necessary to make the system work efficiently. Obviously, therefore, consideration must be given in the very early stages to the associated loading and unloading equipment as well as the special harvesting equipment which is so necessary. Up-to-date capital costs for towers with a capacity of approximately 17,000 cubic feet together with, as far as possible, standardized loading, unloading and harvesting equipment have been brought together in Table 1. Such equipment would be adequate to meet the requirements of an 80 cow herd fed 50 lb per cow per day during a winter period of up to 180 days.

To reiterate—the important points are:—(1) the proportion of total capital costs accounted for by the tower itself and hence the need to consider the capital implication of the entire system, and (2) the tremendous range in net capital costs from one type to another. Are these costs justified on the basis of lower wastage rates, longer life or some other advantage? So far, very little has been published on these points.

Labour requirements

In the survey the saving in labour was the chief reason given for buying a tower silo. This reason can be interpreted in a number of ways—ranging from the expected saving in manual work associated with mechanical feeding to expanding the business without employing an extra man, or actually reducing the labour force in some instances. Most farms in the U.K. are far too small to reap the full benefits of labour saving devices, and there is, therefore, little prospect of a reduction in the labour force on the majority of farms. Rather an expansion of production with existing labour is more relevant. Too much should not be made, therefore, of reduction in labour except on the bigger farms where this would be a distinct possibility.

Wastage in conservation

The farming community is becoming increasingly aware of the potential of grazing and many have acquired the necessary skill and confidence to use it to good effect. Similar progress has not been achieved in conserving grass. The spate of new systems and the adaptation of old ones bear testimony to the fact that successful conservation has so far eluded most farmers. Indeed one of the features of the post-war period is the rapidity with which scientists change their stance and manufacturers adapt and modify designs as each new development proves disappointing in practice. The objective seems to be a

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technique which is cheap to operate, insulated against the effect of adverse weather, rapid in dealing with drops and reliable in producing an end product capable of providing livestock with maintenance requirements and a substantial part of their production requirements as well. Above all else, the search continues for a technique which is capable of lowering and preferably eliminating the enormous wastage which occurs with most techniques at the moment. Is there any evidence that tower silos reduce wastage in conservation?

Claims are being made in the farming press for a 25% and even 50% increase in stocking rates as a result of the reduced wastage rate. At the same time, figures of losses of 5% or even less are also bandied about with little reference to what the figures imply. More reliable evidence is needed on this particular point of wastage rates. Perhaps the most comprehensive data come from Bridgets' where comparisons between clamp and tower silage have been made over a two-year period. Identical grass was used in these experiments and as we would expect the quality of the final product was the same with both techniques. There was, however, a difference in the amounts of product available for feeding. It is well worth repeating these points:—

1. In cases where grass of identical analysis is conserved in different ways and with reasonable care, then the end product available for livestock is of similar quality.
2. The quantities available for feeding differ with different techniques because of the varying wastage rates which occur, and
3. the fact, which should always be borne in mind in budgeting, that a lowering of wastage rates only affects the performance on the conserved area of grass—the grazed area may remain unchanged. It follows that a 10% fall in wastage rates does not mean that stocking rates can be increased by 10%, and
4. wastages in the field are still considerable with tower silo systems and, therefore, even with these systems the conservation process is still at the mercy of the weather.

It should be emphasized that unless grassland management changes, the only benefit we can expect from the introduction of tower silos comes from changes in stocking rate and this is not likely to rise by more than 5% to 10%.

Quality of the conserved product and its effect on performance

The analyses of conserved grass products undertaken by the advisory service and the various commercial firms which offer analytical facilities need to be examined thoroughly.

The numbers of samples analysed each year should provide very reliable indications of any real differences which might exist in the product conserved by different techniques. At the moment there seems to be a marked reluctance to examine such data and perhaps an even greater reluctance to publish them. It is true that tower silage samples with very encouraging analysis are often quoted by similar examples of high quality can also be cited for other conserved products. In the absence of reliable evidence it seems reasonable to assume that no significant differences exist between grass products conserved in different ways. This situation is likely to persist unless changes are made in grassland management.

As part of the Exeter study, feeding records for the dairy cows were collected and these have been related to the theoretical nutrient requirements of the animals for both maintenance and production. The preparation of data of this nature is not easy because there are so many variable factors for which estimates have to be used. For instance, accurate measures of the quantity of home grown foods used are not always available and the estimates of the farmer, which may contain substantial errors, have had to be used. Nevertheless, this exercise has been undertaken in the belief that it is unlikely that all estimates would be biased in the same direction.

TABLE 2

Relationship of Nutrients fed for Theoretical Requirement for Cows in Milk—Exeter Province 1965/66

Relationship of nutrients fed to theoretical requirements	*S.E.*	*P.E.*
	Number of readings	
Over 200%	0	5
150-200	5	7
125-150	7	6
100-125	7	1
Less than 100	3	3
Total	22	22

Analyses of the nutritional value of samples of tower silage have been used in compiling the data in Table 2. It suggests that most farmers tend to overfeed their dairy cows, particularly with protein. Compared with theoretical requirements, five readings for energy showed overfeeding of between 50% and 10%, and five readings for protein overfeeding in excess of 100%. There are, therefore, some indications that marked economies can be made, particularly in the protein fed to the dairy cows in the sample. It is realized, of course, that the sample is small and generalization somewhat dangerous but these shortcomings are unavoidable in the primary stages of any development.

An assessment of the levels of production (in addition to maintenance) obtained from high dry matter silage was made for each reading taken on the dairy farms in the sample. This enabled a grouping of these readings according to the estimated gallonage obtained from the product. The results are set out in Table 3.

TABLE 3

Comparison of Tower Silage Analyses and Milk Production Results—Exeter Province 1965/66

Details	**Group I*	*†Group II*	*‡Group III*	*All Farms*
Analysis°				
% D.M.	45.1	47.2	46.4	46.3
pH	5.2	4.4	4.8	4.7
% Crude protein in D.M.	13.9	14.0	15.5	14.5
% Crude fibre in D.M.	30.5	31.7	29.3	30.5
Estimated % S.E.	22.7	22.2	22.2	2.23
Estimated % P.E.	4.2	3.9	4.4	4.1
Daily yield/cow in milk (gal) from°	S.E. / P.E.	S.E / P.E.	S.E. / P.E.	S.E. / P.E.
Tower Silage	nil / 0.3	0.3 / 0.4	1.2 / 1.2	0.6 / 0.7
Concentrates and other	2.9 / 2.6	2.1 / 2.0	1.3 / 1.3	2.0 / 1.9
Total	2.9	2.4	2.5	2.6
Tower Silage fed°				
lb/cow/day	43	59	52	52
lb D.M./cow/day	18.8	17.3	24	13.8

*Group I. on S.E. basis NIL production from tower silage
†Group II. on S.E. basis 0.1-0.9 gallons/cow in milk from tower silage
‡Group III. on S.E. basis more than 0.9 gallons/cow in milk from tower silage.

Three groupings emerged, the first with tower silage making virtually no contribution to production, the second with readings of between 0.1 and 0.9 gallons per cow per day, and the third group with readings in excess of 0.9 gallons. The basis of the three groups was production according to starch equivalent requirements, but the production from the protein contained in tower silage is also set out. In Group 1, cows produced no gallons from the energy content of the silage, but managed to yield 0.3 gallons per cow per day from the protein. Group 3 contained the readings with the highest levels of production from tower silage—1.2 gallons from both starch and protein.

The contribution of tower silage to milk production is, of course, dependent on such factors as the daily yield of the cows, constituents of the ration, the quantity of silage and other foods fed as well as on the analyses of the different foodstuffs. The herd variation in daily yield per cow in milk was not great, and the average yield was 2.6 gallons. All farmers relied heavily on tower silage and concentrates while hay made only a minor contribution. The analyses disclosed very few obvious differences in the three groups yet the differences in production obtained from tower silage were quite substantial. It is true that there was a fairly wide range in the quantities fed (measured on the basis of both green matter and dry matter) but the cows in the group with the highest production did not receive the largest quantities of silage and the quality in this group was little better than in the other two. It does seem, therefore, that the superior performance recorded in Group 3 was the result of a more meticulous system of rationing the dairy cows. The average picture showed a production of about half a gallon in addition to maintenance from 52 lb of tower silage with 46.3% dry matter. In theory the quality and quantities of tower silage fed in each group were adequate for more production than was in fact achieved.

The foregoing data, much of them derived from the Exeter study, have been used in budgeting the effect of introducing tower silo systems. The assumptions are:—

1. Capital has been written off completely over 10 years and interest has been charged on half the capital initially invested.
2. No reduction in labour has been allowed.
3. The effect of reduced wastage on stocking rate has been estimated at about 5%, and
4. Performance from 50 lb of tower silage was assumed at four levels—maintenance only and maintenance plus production of ½ gallon, 1½ gallons and, when supplemented with 7 lb barley, 3½ gallons of milk.

These have been used for all towers because in the absence of reliable information to the contrary, quality and wastage rates have been assumed to be the same Similarly the same running and maintenance costs have been included for all towers, although it is realized that there may be some differences.

SITUATIONS EXAMINED

A comprehensive treatment of all the different situations facing farmers contemplating the introduction of tower silage systems has not been attempted because it would involve an enormous amount of work and the purpose of this paper is to highlight the heavy capital investment involved in tower silage systems and the consequent need to examine all the factors which may affect the returns derived from the system. The budgets which have been prepared do in fact concentrate on the more usual situation in British farming—the introduction of one tower and the necessary allied equipment. Brief reference is then made to the introduction of a second tower Finally, attention is drawn to the rather unusual situation where a farmer has no facilities for conserving grass and capital has to be invested in buildings and machinery

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equipment for one or other of the different conservation systems.

One Tower Silo and Allied Equipment

The impact of two major benefits are examined here—increased stocking rate and improved quality. The effects of both these factors have been estimated for dairy herds averaging 850 gallons and 1000 gallons per annum and with all the year round calving pattern as well as calving in October and November.

An increased stocking rate of about 5% as a result of reduced wastage rates has been assumed. This has been applied to cows with four different levels of performance from the conserved product:—

i maintenance only

ii maintenance and the production of ½ gallon of milk

iii maintenance and the production of 1½ gallons of milk

iv maintenance and the production of 3½ gallons of milk with 7 lb barley being used to take advantage of excess protein.

The situation has also been examined wherein the conserved product is improved and replaces concentrates in the following manner:—

i maintenance and the production of ½ gallon of milk

ii maintenance and the production of 1½ gallons of milk

iii maintenance and the production of 3½ gallons of milk with 7 lb barley being used to take advantage of excess protein.

Two Towers and Allied Equipment

Attention has already been drawn to the fact that the net capital cost of the tower itself, is well under 50% of the total net cost of the entire system. It is also known that much of the allied equipment would be adequate for a second tower. It follows that in cases where a second tower can be justified the net capital cost per ton of storage capacity is reduced quite enormously. In this respect there is also scope for neighbours to share some of the loading and harvesting equipment with obvious advantages as far as the capital outlay is concerned.

Investment in different conservation techniques

Normally, capital is invested in tower silo systems by farmers who are already equipped to conserve grass in other ways. For instance, most farms have storage facilities for hay and silage and also have the basic machinery and equipment for coping with grass. Some farms may lack such facilities and each alternative system of conserving grass must be examined in depth.

TABLE 4
Summary of % Total Returns on Capital and % Returns available to Farmers on Investments in Tower Silos for Grass

	SITUATIONS												
	Returns on Capital	*Vitreous Enamel Bottom Unloading*			*Vitreous Enamel Top Unloading*			*Concrete Stave*			*Galvanised*		
AVERAGE ANNUAL YIELD		B	C	D	B	C	D	B	C	D	B	C	D
		per cent											
I 850 gallons with cows calving all the year round	Total	18.1	36.7	46.6	18.9	38.2	48.6	20.7	42.0	53.4	14.6	39.7	50.6
	Avllble to frmr	Nil	8.0	14.7	Nil	9.1	16.2	Nil	11.9	19.6	Nil	10.2	17.6
II 850 gallons with cows calving Oct./Nov.	Total	18.8	40.8	5815	19.6	42.6	61.1	21.5	46.7	67.1	20.4	44.3	63.5
	Avllble to frmr	Nil	10.8	22.8	Nil	12.1	24.7	Nil	15.1	28.9	Nil	13.3	26.3
III 1000 gallons with cows calving all the year round	Total	19.9	39.0	50.8	20.8	40.7	53.1	22.9	44.7	58.2	21.6	42.4	55.2
	Avlble to frmr	Nil	9.6	17.6	Nil	10.8	14.2	Nil	13.7	22.9	Nil	12.0	20.7
IV 1000 gallons with cows calving Oct./Nov.	Total	20.5	42.5	62.1	21.4	44.4	64.8	23.5	48.7	71.2	22.2	46.1	67.4
	Avlble to frmr	Nil	12.0	25.3	Nil	13.3	27.2	Nil	16.4	31.7	Nil	14.5	29.0

THE RESULTS

One Tower Silo and Allied Equipment

Returns on capital invested in farming are under close scrutiny at the moment, and claims are being made that farmers are entitled to a fair return on capital. It is extremely difficult to calculate returns on capital and even more difficult to determine what constitutes a fair return. With regard to the former, it is necessary to define precisely the point at which the return is being measured. With regard to the latter, the user of capital judges for himself whether the return is adequate. In this paper returns on capital invested have been calculated after taking into consideration the operating costs of the tower itself. These returns are the monies available to meet interest charges, depreciation and tax liability and to provide the farmer with a return for all his additional efforts. It is realized that these charges will vary from year to year but only the average situation is depicted here. Furthermore, for ease of presentation the information is restricted to the gross returns and, where available, returns to the farmer. One further point needs to be emphasized. It may be claimed by some that certain towers are likely to have a much longer effective life than others, but in this exercise all equipment has been written off over 10 years. This has been done not because it is considered that they will wear out completely in that period but because new technology may make existing equipment obsolescent very rapidly.

were associated with the higher yield levels and patterns of production involving calving the herd in the months of October and November. For the winter herd averaging 1000 gallons the highest returns to the farmer was nearly 32%.

Two Towers and Allied Equipment

Obviously the returns which are obtained from the two tower set-up are going to be far higher because the net capital cost of providing storage and feeding facilities per ton of silage is considerably lower. The information in Table 5 illustrates this.

Capacity is doubled with additional investments ranging from 42% to 48% of the original investment. Therefore, the introduction of a Two Tower Silo system can be justified at a lower level of performance.

TABLE 5
Net Capital Costs of Two Silage Towers and Allied Equipment
(capacity approx. 17,000 cubic feet each and based on January 1967 price)

Type of Tower	*Galvanised*	*Concrete Stave*	*Vitreous Enamel*		*Glass Fibre*
			Top Unloading	*Bottom Unloading*	*Top Unloading*
	£	£	£	£	£
Tower Silo	4,200	3,458	4,746	5,342	5,460
Allied Equipment:					
Loading & Unloading	2,605	2,605	2,605	2,419	2,894
Harvesting	2,050	2,050	1,050	2,050	2,050
Total	8,855	8,113	9,401	9,811	10,404
% Increase over Total Cost of one-Tower system	42	42	47	47	48

The returns on capital invested in different tower silo systems are set out in Table 4. The information relates to the combined effect of increased stocking rates and concentrate substitution at three different levels. Increased stocking rate alone provided additional returns which were inadequate to meet the interest charges and depreciation involved. Therefore, at increased stocking rates of only 5% it would be unwise to invest in the tower silo system.

At both yield levels and the two seasonal production patterns assumed, the combined effect of increased stocking rate and the production of half a gallon of milk from tower silage provided returns which failed to give the farmer any reward for his enterprise and effort.

With the production of 1½ gallons of milk, returns to the farmer with herds averaging 850 gallons and calving all the year round ranged from nearly 12% with the cheapest system to 8% with the most expensive, and with the production of 3½ gallons from tower silage and 7 lb of barley the return to the farmer reached the very satisfactory level of nearly 20% with the concrete stave and nearly 15% with the vitreous enamel bottom unloading system. It was noticeable that the higher returns

Budgeting a New Conservation System

Numerous systems can be used to provide ruminant stock with the basic roughage part of the diet during the indoor winter period. These, together with their capital costs and the probable margin over total purchased feed are set out in Table 6.

Of the systems applicable to most farms, the vacuum silage technique holds out great promise because of its very low capital requirements and also the reasonable end product which it provides. The tower silage system with the cheaper concrete stave tower is also very attractive to the person who is starting from scratch. It does appear, therefore, that the tower silo system may play a significant role in such situations in the future particularly where labour can also be reduced.

SUMMARY

The magnitude of the cost of necessary equipment associated with tower silos makes the consideration of the entire system absolutely imperative. It also makes the

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TABLE 6
Capital Costs and Margins for different conservation systems

ITEM	SYSTEM							
	Clamp silage	*Tower silage* (1)	*Tower silage* (2)	*Vacuum silage*	*Barn dried hay*	*Hay*	*Purchased hay*	*Barley, straw and balancer*
	£	£	£	£	£	£	£	£
Net capital cost	3,637	5,729	6,686	2,545	4,370	3,072	1,092	1,092
Annual depreciation and interest charges	491	774	903	344	590	415	147	147
Direct costs excluding harvesting	—	80	80	10	156	—	—	—
Total annual charges	491	854	983	354	746	415	147	147
Gross output of dairy cows	9,367	10,148	10,148	9,627	10,018	9,367	10,148	10,148
Gross margin from barley	—	—	—	—	—	—	1,300	1,300
Total	9,367	10,148	10,148	9,627	10,018	9,367	11,448	11,448
Purchased feed:—concentrates	2,500	2,709	2,709	2,570	2,674	2,500	2,709	2,709
other	—	—	—	—	—	—	1,705	1,645
Total purchased feed	2,500	2,709	2,709	2,570	2,674	2,500	4,414	4,354
Margin over total purchased feed	6,867	7,439	7,439	7,057	7,344	6,867	7,034	7,094
Margin over purchased feed and annual charges	6,376	6,585	6,456	6,703	6,598	6,452	6,887	6.947
Additional margin over clamp silage	—	209	80	328	222	76	511	571

introduction of a second tower a more attractive possibility because storage and feeding capacity can be doubled with only a comparatively small percentage increase in capital investment.

The introduction of the Tower itself can only have an effect on wastage rates and through these on stocking rates. The claims made for Towers in reducing waste have been over generous and it is well to remember that the reduced waste only affects the conserved area of grass so that its effect on overall stocking rate might not exceed 5%. The introduction of a Tower Silo system based solely on the returns from increased stocking of this magnitude cannot be justified.

Tower silo systems make possible a change for the better in grassland management, but this change does not automatically follow. However, in order to justify investment in this system, particularly at the one tower level, it seems vital to produce a product which is capable of replacing concentrates for 2½ gallons and preferably produce a surplus of protein capable of producing a further 2 gallons when supplemented with Barley.

Finally it must be remembered that there are some situations where no facilities exist for conservation. In such cases the Tower Silo system shows up better than the clamp silage system.

OBITUARY

The Council records with deep regret the death of the following members:

BROWN, Mjr. D. T.	Member
CHIVERS, F. J.	Associate
COUTTS, D.	Associate Member
DAVIES, Dr Cornelius	Hon. Member
HENDERSON, J. R. G.	Graduate
SHUTTE, R. V.	Associate
SLATER, J. K. W.	Member
SMART, S. S.	Associate

POSSIBLE TRENDS IN THE MECHANIZED FEEDING OF CATTLE—*from page 105*

system results in a yearly saving something approaching half an acre per cow unit compared with a conventional clamp system.

9. With small units the cost of the tower system is disproportionately high. In comparing the conventional clamp with a tower system the study carried out at Peepy and West Newham indicated that the use of tower silos could be given serious consideration when the herd size approaches the equivalent of 80 cow units.
10. It was shown that on both systems (self feed silage and tower silage) the bulk requirement per cow unit was approximately equivalent to two tons of dry matter for a winter period of 180-200 days.

Let us then look at this aspect of mechanization in relation to the broad problem of British agriculture.

At present in Great Britain we have between 500 and 600 forage towers representing only .04% of the total conserved roughage produced on our farms. Most roughage is conserved in the form of hay, with considerable losses in food value—total losses may be 30 to 50% of the crop at cutting, Nevertheless, hay is a very flexible and saleable commodity.

However, as land values continue to rise and counties the size of Middlesex get swallowed up by buildings etc., every 10 years, it becomes more important to make better use of improved conservation techniques. At the same time, because of reducing profits in farming, mechanical feeding systems will lead to intensification, cut down labour costs and save general wastage.

The ever-increasing world population and the particular problem in our own country will no longer allow us to ranch our farming. The efficiency of food conservation and food conversion will increase year by year leaving only specialists in various enterprises to provide one's needs. Moreover, the family farm of the future will probably carry 100 cows and we will see the introduction of factory farm units running into thousands of head of livestock.

Without doubt changes are being accelerated by the financial assistance which is now available under various grant aid schemes.

Automation

The most important field of development could come from the application of electronics and the complete automation of the whole feeding system. I hope, as a practical farmer, to see a much greater use of the techniques which have proved so beneficial to industry during these last few years.

THE APPLICATION OF FERTILIZER IN AGRICULTURE

AN ASSESSMENT OF THE AGRONOMIC REQUIREMENTS OF FERTILIZER APPLICATION

by

M. R. J. HOLMES, MA*

Presented at the Spring National Meeting of the Institution in the Farm School, Milton, Cambridge
Thursday 28 *March* 1968

In common with most farm machinery, the design and operation of fertilizer distributors must be a compromise between technical excellence and good commercial sense. If evenness of application can be improved at no extra cost it is obviously desirable; but in most cases the quality of work done can only be improved by increasing the selling price of the machine or reducing the rate of work and therefore increasing the operating cost—or both.

This paper presents a number of considerations that should help designers and farmers to choose the level of performance at which to aim, by studying the effects which various degrees of uneven distribution can have on crop yields and crop quality. Uneven distribution may also touch the farmer's pride—especially when it occurs on a roadside field.

Yield losses result essentially from the curvilinear nature of the yield response to fertilizer (Figure 1). Taking a very simple case, if part of the area receives a higher than intended rate of application and another part a correspondingly lower rate, the extra yield (Y-X) in the first area will be less than the loss of yield (X-Z) in the second area. Figure 1 also shows that the degree of curvature increases as the application rate approaches that required for maximum yield. This has two effects on yield loss. The overall loss will increase more than proportionately to the degree of unevenness, since as the latter increases Y-X will not increase as fast as X-Z increases. Also, for a given degree of unevenness the difference between Y-X and X-Z will increase with the degree of curvature, i.e. as the rate approaches that for maximum yield. Two further factors that will affect the financial loss to the farmer are the size of the response to fertilizer and the value per unit weight of the crop.

The most direct way of assessing the effect of yield of uneven application would be from experiments in which different degrees of unevenness had been simulated. Unfortunately no satisfactory evidence for such experiments is available for United Kingdom conditions. In Holland, Prummel and Datema[1] assessed the effect of uneven application in field experiments and found yield losses increasing in magnitude with the degree of unevenness. They also calculated the losses to be expected from uneven application using nutrient response data from field experiments and found that the two methods of assessment gave comparable results.

The use of data from ordinary experiments measuring response to fertilizer is subject to a number of limitations. However, if these are dealt with by reasonable assumptions, an approach based on data of this kind can be very useful. The first limitation is that if the individual areas to which different rates of fertilizer are applied are sufficiently small, uneven application may be unimportant because all individual plants will draw nutrients from areas receiving both high and low rates of fertilizers. In this way, all individual plants would effectively receive the mean fertilizer application rate. Little information exists on the maximum area over which unevenness can be rendered unimportant but Prummel and Datema state that inequalities in rate of application were only important when the individual patches were greater than 0.5 m.[2] It seems likely that factors such as plant population and row width will have a considerable influence on the minimum size of area that is important in this respect. The pattern of fertilizer application should therefore be assessed using areas 1 ft to 1.5 ft wide as the units from

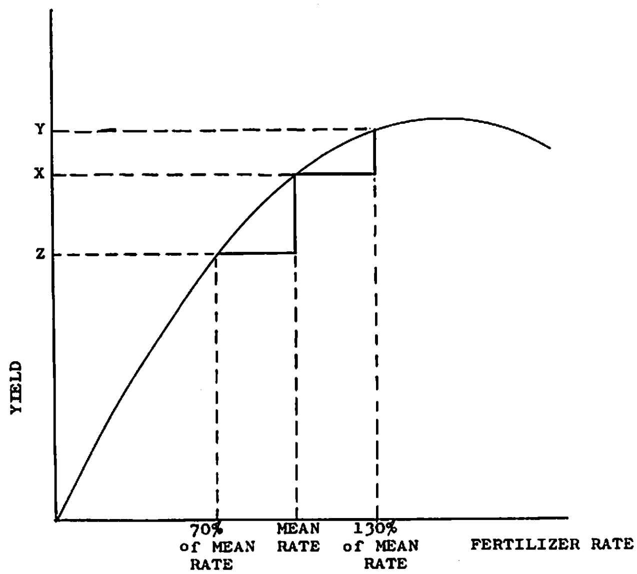

FIG. 1. TYPICAL RESPONSE CURVE SHOWING EFFECT OF UNEVEN FERTILIZER APPLICATION ON YIELD

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which recordings are obtained. Edge effects between areas of low and high application will even then tend to offset the yield losses resulting from uneven application, so that calculations of yield losses made from response experiment data, which does not provide an allowance for edge effects, will represent the maximum possible effect of uneven application.

The second assumption relates to the shape that the response curve to fertilizer takes for any situation. It is common experience that the general shape of the curve is as shown in Figure 1, i.e. rising to a maximum and then falling away again at high rates of application. A quadratic equation usually fits the response reasonably satisfactorily and calculations can be made on the loss of response to be expected when fertilizer is applied unevenly. Dickins[2] has calculated this loss for a number of application rates ranging up to that required for maximum response and also in relation to the degree of unevenness of application (Table 1). The latter was expressed in terms of the standard deviation of yields in individual parts of the area to which fertilizer was applied, as a percentage of the overall mean application rate (i.e. coefficient of variation). In the three examples below these calculations are related to a range of practical response situations and the likely loss in response is expressed in current financial terms.

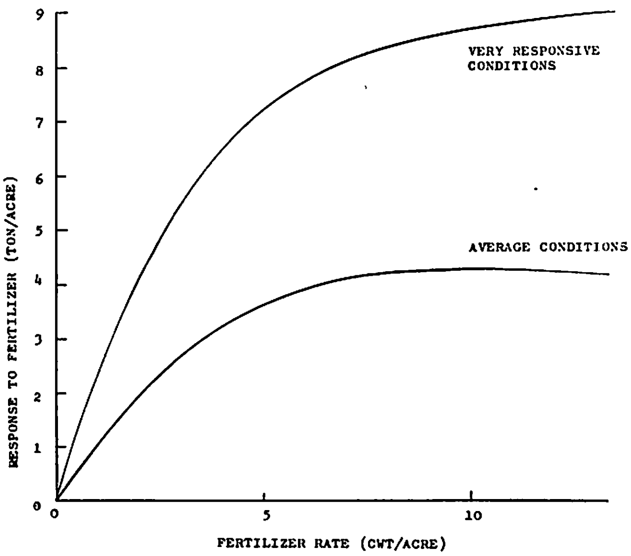

FIG. 2. RESPONSE OF POTATOES TO 1 - 1 - 1½ RATIO COMPOUND FERTILIZER

TABLE 1

% loss of response to fertilizer in relation to rate and unevenness of application (quadratic response function)

Fertilizer rate (% of rate required for maximum response)	*% loss of response to fertilizer*			
	Unevenness of application (Coefficient of variation, %)			
	10	15	25	50
100	1.0	2.2	6.2	25.0
95	0.9	2.0	5.6	22.6
90	0.8	1.8	5.1	20.4
80	0.7	1.5	4.2	16.7
70	0.5	1.2	3.4	13.5
60	0.4	1.0	2.7	10.7
50	0.3	0.8	2.1	8.3
25	0.1	0.3	0.9	3.6

Potatoes, the first example, are a high value crop normally very responsive to fertilizer, on which optimum fertilizer rates closely approach those required for maximum yield. Data from a recent series of experiments[3] have been used to provide response curves for (a) an average situation and (b) an extremely responsive situation (Figure 2). In both cases a quadratic form of response curve has been used. From these responses and from Table 1, the actual financial loss can be calculated for various levels of fertilizer application and for a range of degrees of unevenness of application (Table 2). These losses increase with rate of application (up to that required for maximum yield), and with increasing unevenness; they are naturally larger the greater the yield response to fertilizer. The optimum fertilizer rate for potatoes is about 95% of that giving maximum yield (slightly less than this in the average situation and slightly more in the very responsive situation). No absolute figure can be given for the maximum acceptable financial loss, since this will depend on management considerations such as the initial and running costs of alternative distributors. However, it seems reasonable to be averse to losses in excess of £1 per acre (between 1 and 2% of the average gross margin of the crop). It follows that the unevenness of application should not have a coefficient of variation (i.e. the standard error of application rates on individual areas as a % of the mean rate) in excess of 10% under average conditions, while for particularly responsive conditions even greater accuracy is desirable.

Nitrogen response in winter wheat is the second example. This is again a responsive crop under most conditions, but one of which the value per acre is much lower, and the optimum application rate is about 90% of that giving maximum yield—not quite so high as for potatoes. Response data from unpublished Levington experiments is illustrated in Figure 3, and Table 3 shows a generally much lower level of financial loss for winter wheat than for potatoes. However, similar relationships

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TABLE 2

Potatoes. Financial loss resulting from various degrees of unevenness of application of compound fertilizer

	Financial loss (£ per acre)							
	Average conditions				*Very responsive conditions*			
Fertilizer rate (as % of rate required for maximum yield)	*Unevenness of application (Coefficient of variation, %)*				*Unevenness of application (Coefficient of variation, %)*			
	10	15	25	50	10	15	25	50
100	0.73	1.61	4.54	18.32	1.49	3.29	9.27	37.36
95	0.66	1.46	4.09	16.53	1.34	2.98	8.35	33.70
90	0.58	1.30	3.70	14.79	1.18	2.66	7.54	30.16
80	0.50	1.06	2.97	11.81	1.00	2.15	6.01	23.89
70	0.33	0.80	2.27	9.03	0.68	1.63	4.61	18.30
60	0.25	0.62	1.67	6.61	0.50	1.25	3.38	13.40
50	0.17	0.44	1.16	4.57	0.33	0.89	2.34	9.23
25	0.03	0.10	0.29	1.16	0.06	0.19	0.58	2.33

Notes: 1. At £16 per ton of potatoes.
2. Calculated from Dickins[2] and the data illustrated in Figure 2.

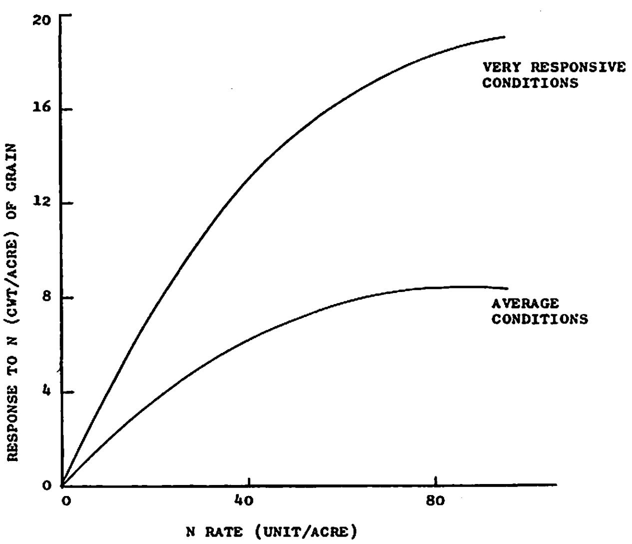

FIG. 3 RESPONSE OF WHEAT TO NITROGEN

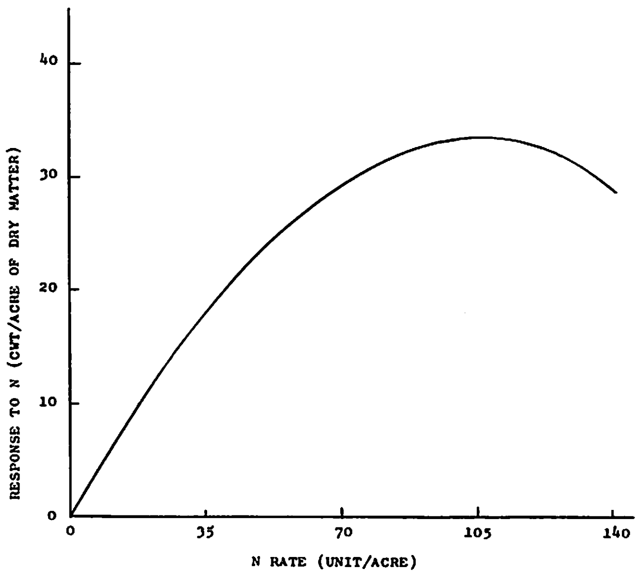

FIG. 4 RESPONSE OF GRASSLAND TO NITROGEN IN AN EXPERIMENT AT LEVINGTON (ONE CUT)

hold for rate of application, degree of unevenness and size of fertilizer response. Selection of a permissible level of loss is again subjective, but because of the lower value of the crop and the lower costs of fertilizer application for this crop than for potatoes it seems reasonable to take the lower limit of 10/- per acre (again between 1 and 2% of average gross margin). On this basis, unevenness giving a 15% coefficient of variation is a suitable upper limit.

The third example taken is nitrogen application to grassland, a responsive crop, but one of low value per acre and on which the nitrogen rates used are usually very much below those giving maximum yield. Data from an unpublished Levington experiment investigating the nitrogen requirements of an all grass sward are shown in Figure 4, and give the degree of loss of dry matter yield shown in Table 4. It seems likely that most farmers would accept a loss of 100 lb/acre of dry matter, and on this basis a 20% coefficient of variation is acceptable for normal application rates—up to 80 units/acre of N. However, 100 lb of dry matter could well be valued at over 10/-, and if a lower limit of 50 lb/acre should be taken, then 15% variation should not be exceeded. On the other hand, under grazing management, or with several applications of fertilizer per year, uneven application will be less important because of the compensating effects of successive applications of fertilizer or of nitrogen returned in dung and urine.

The arable examples above are in the context of the use of optimum fertilizer rates, while the grassland example pre-supposes the use of a normal application rate on the rising, near-linear part of the response curve. Some arable farmers are known to use fertilizer rates much above optimum, particularly for potatoes and sugar beet, and if this is associated with severe yield depressions, as may on occasions be the case, uneven application may be especially undesirable.

The overall conclusion from all three examples is that to give acceptably small yield losses, unevenness of application should not exceed 10% on the more valuable cash crops or 15% on cereals or grassland. A machine for general use should therefore give a coefficient of variation less than 10%.

It is important to distinguish this measure of unevenness from that used in many test reports, where the maximum range of application rates is quoted as a percentage of the mean rate. As an approximate guide, variation expressed as a maximum range gives a value about twice the one obtained when the measure is coefficient of variation. Thus, while 10% coefficient of variation is a reasonable upper limit the maximum range can be up to 20% on either side of the mean.

In terms of crop appearance a degree of unevenness giving a 10% coefficient of variation would often be discernible only with difficulty, and only on responsive crops. Thus any obviously uneven crop growth is not only untidy but also likely to be associated with appreciable financial loss.

Uneven application may well lead to lodging of cereals or of grassland for hay on the areas receiving the highest fertilizer rates. In so far as lodging affects yield, the response curves from which the losses in Table 3 and 4 are calculated take account of it, so that it is not a factor causing further loss. Variation within the limits considered acceptable above is unlikely to cause appreciable lodging additional to the level that might occur with even application. Thus where uneven application is sufficiently marked to cause obvious patchy lodging it is also likely to give rise to an unsatisfactory level of financial loss through yield depression.

TABLE 3

Winter Wheat

Financial loss resulting from various degrees of unevenness of application of nitrogen

N rate (as % of rate required for maximum yield)	*Financial loss (shillings per acre)*							
	Average conditions				*Very responsive conditions*			
	Unevenness of application (Coefficient of variation, %)				*Unevenness of application (Coefficient of variation, %)*			
	10	15	25	50	10	15	25	50
100	2.2	4.8	13.7	55.1	5.0	10.9	30.7	123.8
95	2.0	4.4	12.3	49.8	4.5	9.9	27.7	111.9
90	1.7	3.9	11.1	44.4	3.9	8.8	25.0	99.9
80	1.5	3.2	8.9	35.5	3.3	7.1	19.9	79.2
70	1.0	2.4	6.9	27.3	2.3	5.4	15.3	60.9
60	0.7	1.9	5.0	20.0	1.7	4.1	11.2	44.4
50	0.5	1.3	3.5	13.8	1.1	3.0	7.8	30.8
25	0.1	0.3	0.9	3.5	0.2	0.7	2.0	7.8

Notes: 1. At 25/11 per cwt of grain.

2. Calculated from Dickins[2] and the data illustrated in Figure 2.

TABLE 4

Grassland

Loss of yield resulting from various degrees of unevenness of application in relation to nitrogen rate (one silage cut)

	Loss of yield (100 *lb/acre of D.M.*)			
	Unevenness of application (Coefficient of variation, %)			
	10	15	25	50
100	0.33	0.73	2.07	8.34
90	0.26	0.59	1.68	6.74
80	0.22	0.48	1.35	5.35
70	0.15	0.36	1.03	4.10
60	0.11	0.28	0.76	3.00
50	0.08	0.20	0.53	2.08
25	0.01	0.04	0.13	0.53

Note: Calculated from Dickins[2] and the data illustrated in Figure 4.

Crop Quality

It is well established that fertilizers, especially nitrogen, can affect crop composition and quality. One example is the nitrogen content of barley, which is increased quite markedly by normal or high rates of nitrogen as illustrated by the example in Figure 5. If in this example 70 units

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of nitrogen were applied unevenly, there would be two effects: the uniformity, in terms of nitrogen content, of the barley harvested from the crop would be reduced, and its mean nitrogen content would be increased, because of the upward curvature of the response. Both effects could be undesirable in malting barley but feeding barley could benefit from the higher nitrogen content. Similar undesirable effects could be expected wherever fertilizer affects crop composition in this way, for example when

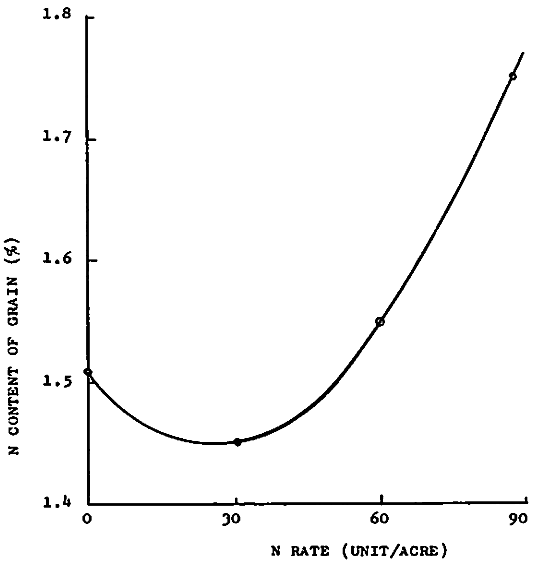

FIG. 5 EFFECT OF NITROGEN APPLICATION ON NITROGEN CONTENT OF BARLEY GRAIN IN A FIELD EXPERIMENT IN SUFFOLK

high nitrogen rates depress the sugar content of sugar beet.

In assessing the significance of uneven application on crop quality, it is of importance that the effect of fertilizer rate on quality is almost always slowly progressive so that only major inequalities in application rate are likely to have serious effects. The effects of limited unevenness, of the order of 10% coefficient of variation, will seldom be important.

Combine Drilling

Uneven application is often associated only with broadcast application. However, irregularities in application rate may be even less desirable when fertilizer is placed, as in combine drilling. Hutchinson[4] showed that a star wheel feed, the most usual mechanism in combine drills at least until recently, often gives very erratic delivery rates. This can affect crop growth not only because of the nutrient effect of the fertilizer but also because at high rates of application placed fertilizer can delay germination and early growth. If some lengths of a row of cereals receive an excessive rate of fertilizer, growth may be seriously retarded or plant population may be reduced. Such effects can occasionally be seen in the field soon after emergence as lengths of drill with forward, vigorous plants alternating with stretches of poor, backward growth. Even application will reduce the danger that, under adverse conditions, combine drilling may seriously affect early growth. However, most experimental evidence on the effectiveness of combine drilling has been obtained with drills that apply fertilizer non-uniformly and the widespread use of more efficient machines should make combine drilling more advantageous *vis-à-vis* broadcasting than the present evidence suggests.

Conclusions

In this paper on fertilizer application the writer has concentrated attention on unevenness, believing it to be the aspect on which an agronomist can provide most guidance. An important part of this guidance is to suggest what degree of crop loss, and therefore of financial loss to the farmer, may result from uneven application. The farmer has then the opportunity so to choose his application machinery and control the process of application that these losses are kept within acceptable limits. The aim of the manufacturer, both of application machinery and of fertilizer, should be that his product is such that satisfactory even application can be achieved without undue expenditure in initial outlay, loss of output, detailed supervision or application costs in the field.

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THE APPLICATION OF FERTILIZERS IN AGRICULTURE

ACHIEVING THE DISTRIBUTION REQUIREMENTS FOR SOLID FERTILIZERS

by

T. L. GREEN, C ENG, AMI MECH E*

Presented at the Spring National Meeting of the Institution in the Farm School, Milton, Cambridge on Thursday 28 *March* 1968

The factors that a user of solid fertilizer should consider when assessing a machine are discussed and the characteristics of current machines are reviewed; their costs, hopper capacities, effective working widths and relevant published test reports are summarized in tabular form. Published test reports, and other test data given in the paper on both old and new machines tested under non-ideal conditions, show that granular fertilizer can be applied cheaply and to the required agronomic standards by both the small and large solid fertilizer user with currently available machines.

A method of determining the evenness of distribution when fertilizer is applied by an aeroplane, is described and the results of tests using a prilled fertilizer are shown in graphical form. Test results are also given for farmers' and contractors' machines, in an 'as found' condition when spreading compound granular, prilled and blended granular fertilizers. The method used to determine the evenness of distribution of the nutrients of a blend is described and the test results given illustrate the importance of having correctly size-matched constituents in a blend. That section of the paper on the cost of applying solid fertilizer includes a nomograph for determining the rate of working when different machines and different loading methods are used.

There has been a considerable improvement in the design and quality of solid fertilizer applicators in recent years and there are many machines now available capable of applying fertilizers to the agronomic standards specified by Holmes[1], i.e. so that Coefficient of Variation of the Application Rate does not exceed 10% on high value crops and 15% on low value crops.

However, even with the best equipment available, uneven application can occur due to one or more of the following causes:

(a) An unsatisfactory machine—one unsuitable for the operating conditions or one that has been badly damaged or maintained.
(b) Mal-operation of the machine.
(c) The quality or properties of the fertilizer adversely affecting the performance of the machine.

It is the joint responsibility of the machine designers and manufacturers, the fertilizer manufacturers, the farmers and the operators to ensure that these do not occur. This is essentially a communication problem and therefore no apologies are made to agronomists, chemists and engineers for including in this paper explanations of terms with which they are familiar but with which farmers and operators are, possibly, not so familiar.

1. The Farmer's Problem

The farmer's problem is to decide which is the right machine for the job.

The machines currently used for applying solid fertilizer can be divided into two classes:

(a) Distributing machines, which are used to distribute the fertilizer over the surface of the soil. There are two types: Full Width Machines which drop the fertilizer on to the land so that the width of spread is nearly equal to that of the machine and Broadcasting Machines which throw the fertilizer so that the width of spread is greater than the width of the machine.
(b) Placement Machines, which place the fertilizer in a definite region relative to the soil or plant.

Even the fundamental decision on whether to place or distribute the fertilizer can only be correctly made if characteristics of the available machines are known: the overall cost of applying the fertilizer must always be considered against the yield and Holmes has shown how the yield is affected by the evenness of application.

The Coefficient of Variation of 10%, that Holmes has stated to be the standard required when applying fertilizer to high value crops, is a precise way of saying that the variation from the mean application rate shall:

1. Over 66% of the surface not exceed ± 10%
2. Over 95% of the surface not exceed ± 20%
3. Over 100% of the surface not exceed ± 30%

The specification for a machine applying fertilizer therefore is: 'Fertilizer shall be applied so that when the application rate is measured on areas not less than 1 foot by 1 foot and not greater than 1½ feet by 1½ feet, the measured variations from the mean rate shall be such that it can be guaranteed that on 95% of the total area the variations from the mean rate will not exceed ± 20% on high value crops and ± 30% on low value crops: over the whole area the variations from the mean application rate shall not exceed ± 30% and ± 45% for high and low value crops respectively'.

But a user of solid fertilizer wants to know not only

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whether a machine can apply fertilizer to this specification under his operating conditions but also:

1. How much skill is required by the operator? Has he or have his employees this skill?
2. How many man/acres per day will it achieve?
3. How often has the machine to be cleaned? Is it easy to clean? Will it be liable to rapid depreciation due to corrosion?
4. How much maintenance will be required to ensure that the machine will continue to perform satisfactorily?
5. What is the availability of spare parts? Who can fit them?
6. How much does the machine cost? Would a cheaper or a more expensive machine be a better investment?

The solid fertilizer user in the U.K. is fortunate in that good, unbiased, test reports on many solid fertilizer applicators have been published by the National Institute of Agricultural Engineering (the N.I.A.E.). An N.I.A.E. Test Report not only shows how accurately a machine applies fertilizer but also gives sufficient information to enable Questions 1 to 4 and the second part of Question 5 to be answered. It must be the responsibility of the user to find the answers to the first parts of Questions 5 and 6; it is hoped that this paper will help him to answer the second part of Question 6.

2. Test Reports

Table 1, which summarizes the data on the popular types of solid fertilizer applicators used in the U.K., shows the N.I.A.E. Reports which have been issued. The fact that 28 reports including 2 Series Test Reports, have been published since 1963, compared with only 8 in the previous 6 years, is an indication of the developments that have been made and the confidence of the manufacturers who voluntarily submit their machines for testing. It must be emphasized that a machine should not be condemned because of the lack of an N.I.A.E. Test Report: testing a machine and publishing a report takes time, and, therefore, test reports are not usually available when a machine is first marketed. Similarly, manufacturers are continually improving their machines and the published test report may not be that of the current model.

TABLE 1

Summary of Solid Fertilizer Application Machinery Available in the U.K.

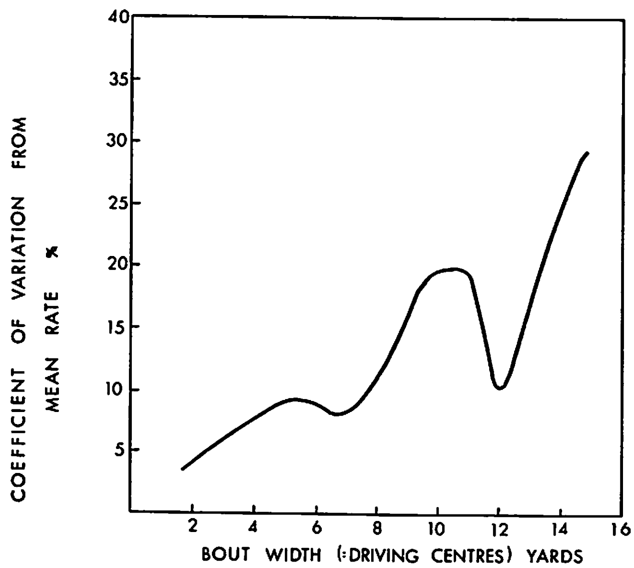
Type of Machine	*Approximate Hopper Capacity (cwt at 60 lb/ft³)*	*Approximate Effective Working Width for Granualr Fertilizer (feet)*	*Approximate Price Range £*	*Relevant N.I.A.E. Test Reports*
Tractor trailed broadcasting distributors with hydraulic motor driven spinning discs and with belt, chain or auger feed	25 to 40	Varies from 15 to 35 but for majority is 21	250 to 500	427, 428, 433, 436, & 444
Tractor trailed broadcasting distributors with p.t.o. driven spinning discs or oscillating spouts and with assisted gravity feed (in some machines)	10 to 25		120 to 250	536
Tractor mounted broadcasting distributors with p.t.o. driven spinning discs or oscillating spouts	4 to 10		40 to 120	226A, 329, 430, 431, 432, 434, 435, 444, 510, 534, & 551
Full width distributors with agitator feed	8 10 12	8 10 12	140 150 160	361 & 565
Full width distributors with rotating plate and flicker mechanism	6 10 13	7 12 17	100 200 250	168 (published in 1958)
Full width distributors with roller feed	10 14	9 12	250 300	
Combine drills	6 7 9	9 10 13	300 370 450	

Methods of determining the application accuracy of a machine are now standardized—the Organization for Economic Co-operation and Development have, for example, recently published a testing code for testing fertilizer distributors[2]—but in the past various methods have been used and the results have also been reported in different ways. The most widely used method, and that now recommended by the O.E.C.D., is to measure the Longitudinal Distribution Pattern and the Transverse Distribution Pattern separately, by weighing the fertilizer collected in a row of trays when the machine is driven along or across them.

Different machines have different application characteristics; the longitudinal distribution of broadcasting

FIG. 1

EFFECT OF CHANGES IN BOUT WIDTH ON THE COEFFICIENT OF VARIATION



distributors is very good and therefore tests on these machines are usually limited to determining the Transverse Distribution Pattern. For many full width and placement machines however, the variations in the longitudinal distribution exceed those in the transverse distribution, and, therefore, both the transverse and the longitudinal distribution patterns are measured when testing these machines.

It is obviously important when comparing the distribution patterns of machines obtained by different methods of testing that the size of the trays used should be taken into account. Differences in the scale of scrutiny are less important when testing broadcasting machines because the patterns vary smoothly across their width of spread, but care must be taken when comparing the results of full width distributors and placement machines because high peaks and valleys may occur close to each other and in a systematic pattern across the width of the machine. When assessing these patterns the readings should, on the basis of Holmes' specification, be combined to make them equivalent to using trays 1 ft or 1.5 ft wide and, unless otherwise stated, the results quoted in this paper have been based on equivalent tray widths or tray lengths of 1 ft.

The Transverse Distribution Patterns of broadcasting machines are usually trapezoidal or triangular in shape and the Overall Distribution Pattern is calculated taking into account the amount of overlapping that will occur when the machine is driven up and down the field at constant bout widths, or driving centres. Fig. 1, a typical result for a broadcasting machine, shows the effect of changes in bout width on the Coefficient of Variation and illustrates that for this machine a 1 yard deviation from a bout width of 12 yards would significantly affect the overall distribution and that, in some circumstances, it would be better to operate at 7 yard centres.

The Coefficient of Variation of the Application Rate is a convenient term to define the distribution characteristics of a machine but it has only been used in recent reports. In earlier reports, only the measured % Variations from the Mean Rate are shown and in the latest reports the terms 'very good, good, fair and poor' have been used. Table 2 shows how these different terms can be compared.

TABLE 2

Comparison of Terms Used by the N.I.A.E. to describe the Distribution Characteristics of a machine

C. of V. as % of Application Rate	5	10	17	>17
Max. measured % variation from mean application rate	±10	±20	±34	> ±34
Described as—	Very Good	Good	Fair	Poor

3. The Development and Characteristics of the Available Machines

3.1 Broadcasting Machines

3.1 (a) *Spinning Disc and Oscillating Spout Mechanisms*
The popularity of these machines is indicated by the number of test reports which have been issued on the different available machines, (Table 1). Although two machines are available with oscillating spouts the most-used mechanism is a spinning disc or discs. When these machines were first introduced on a large scale there were many instances of mal-distribution, but designs have improved, manufacturers' instructions are now more explicit and operators have learnt to handle the machines correctly with the result that they are now very popular machines.

Improvements in design have been accelerated by research carried out at British and foreign universities on how granules behave on a rotating disc and how they

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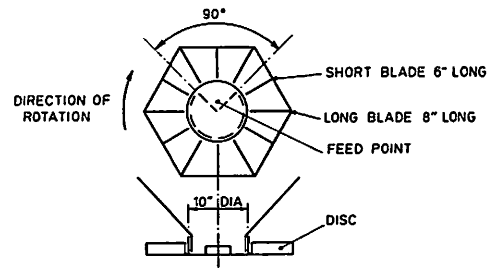
travel through the air[3 4 5]. Fig. 2, based on data in Ref. 3, shows that the angle of flight ($\theta + \psi$) is independent of the angular velocity (ω) of the disc, but is dependent on the ratio of the radius of the feed point (r) to the radius of the disc (R) and on the coefficient of friction of the particle on the disc. Using this data, and other from the same source to predict the particle trajectories, the author has found by statically testing a number of machines that the transverse distribution pattern can be predicted with reasonable accuracy if it is assumed that the coefficient of friction is 0.5. The result of a typical static test, on a now redundant machine, is shown in Fig. 3. In the test the large concrete floor was divided into areas of 1 yd^2 using wooden laths, the fertilizer was spread for one minute and the fertilizer deposited in each sq. yard was weighed. The author has found that this method of static testing is also very useful when determining why a machine is



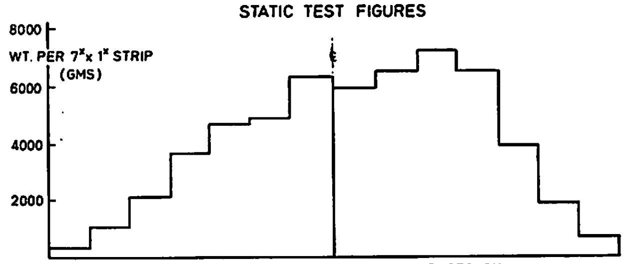
GENERAL ARRANGEMENT OF HOPPER & DISC

PREDICTED ZONE FOR LONG BLADES — DISC SHAFT — PREDICTED ZONE FOR SHORT BLADES

70	170	220	179	116	139	71	96	136	350	615	445	195	52
85	229	415	568	268	161	149	176	223	317	846	992	585	189
76	254	498	822	827	438	167	158	611	1580	2004	1186	482	190
85	249	518	952	1230	1030	717	834	1790	2202	1817	854	291	69
45	147	306	649	1307	1640	2645	2596	2226	1737	782	350	164	25
30	48	112	300	710	1160	1900	1692	1261	720	274	93	31	126
8	13	31	70	184	323	605	268	215	160	66	33	-	-

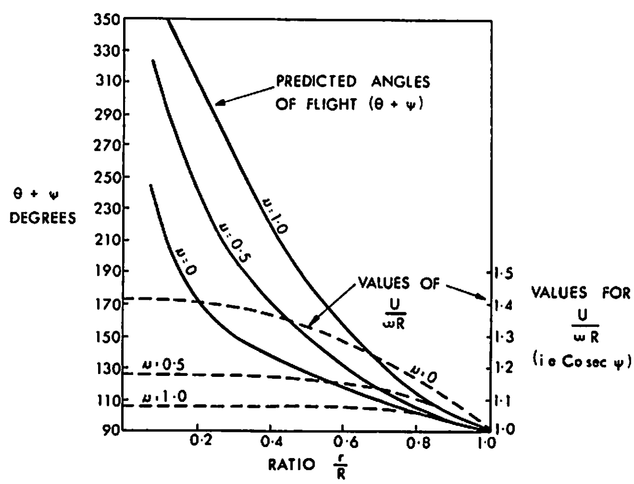
FIGURES ARE WT. COLLECTED (GRAMMES). SQUARES ARE 3' x 3'.

STATIC TEST FIGURES



TRANSVERSE DISTRIBUTION PATTERN BASED ON TEST FIGURES

FIG.3 STATIC TEST RESULTS



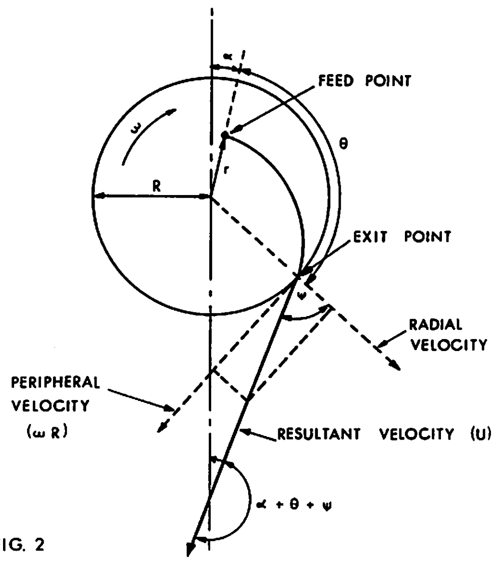


FIG. 2

PREDICTED FLIGHT OF A PARTICLE FROM A ROTATING DISC

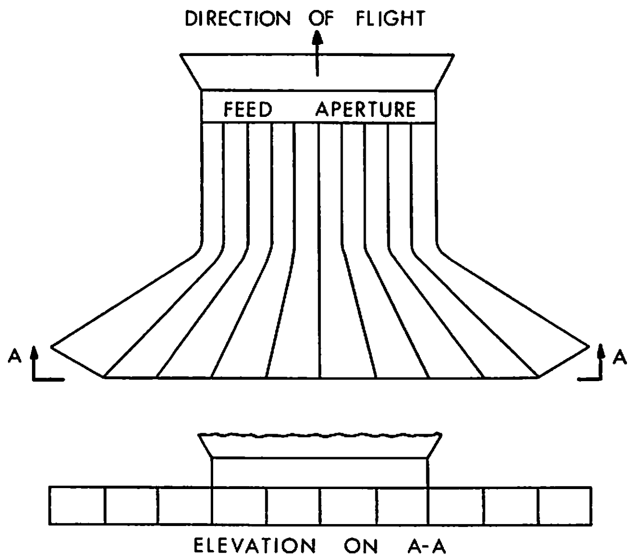
giving a distorted transverse distribution pattern; for example, ricochet from the tractor wheels can be easily measured and often quickly eliminated.

The research work[3] coincided with a growing demand for accurate broadcasting machines and great activity by manufacturers to meet this demand. New models were introduced; designed so that variations in the r/R ratio (of Fig. 2) were small when feed rates changed (thus ensuring that a constant symmetrical transverse distribution pattern was always obtained) and so that a constant disc speed could be more easily maintained. More smaller machines incorporated a p.t.o. driven disc, to replace the previously popular land wheel driven type and on the larger and more expensive machines, an auxiliary motor, usually driven from the tractor hydraulics, with a tachometer was used.

An N.I.A.E. test report published in 1965[6] on 16 broadcasting machines shows that, when driven at ± 1 yard of the optimum bout width, 11 of the machines were capable of applying granular fertilizer at 3 cwt/acre so that the Coefficient of Variation did not exceed 15%, and that for 7 of these machines a Coefficient of Variation of

FIG. 4

VENTURI DISTRIBUTOR



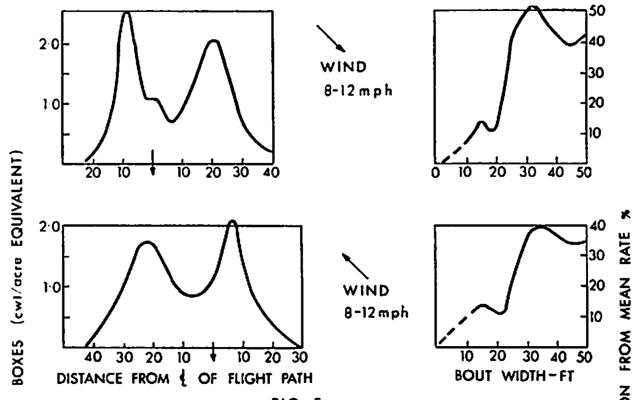


FIG. 5

TEST RESULTS FOR DISTRIBUTOR A

(APPLICATION RATE ≏ 3½ cwt/acre AT 20FT BOUT WIDTH)

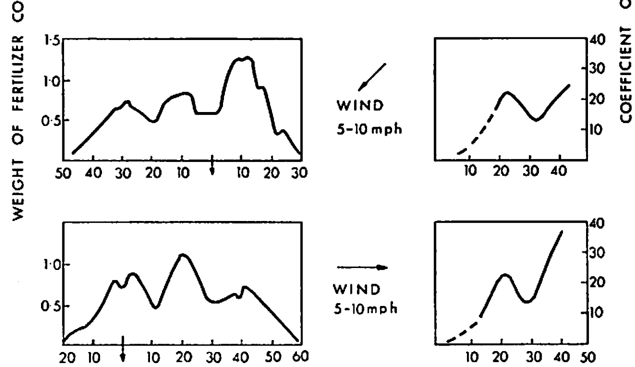


FIG. 6

TEST RESULTS FOR DISTRIBUTOR B

(APPLICATION RATE ≏ 1½ cwt/acre AT 30 FT BOUT WIDTH)

10% or better was achieved. Of the 6 machines designed for application rates of 9 to 12 cwt/acre, 3 applied these rates so that the Coefficient of Variation did not exceed 15%.

Since the publication of this report a number of the machines tested have been improved and a number of new machines have been introduced. Tests by the author on many farmers' and contractors' machines in the field show that many machines can consistently achieve a 15% Coefficient of Variation and a standard of 10% is not exceptional.

Broadcasting machines have many advantages over full-width distributors; they cover the ground faster, are usually cheaper, mechanically simpler, easier to clean and maintain and are more easily transported. They must be carefully operated: but this is true for many machines, and due to the improvements in design already mentioned and because most manufacturers issue good instruction books, the majority of users do not find this difficult. There is a growing tendency for more machines to be operated at bout widths of about 7 yards, whereas in the past bout widths of 12 yards or more were common practice. There is much to be recommended in this tendency; markers are essential when operating at large bout widths, but at bout widths of about 7 yards the previous wheel marks can often be seen and, as shown in Fig. 1, with many machines a deviation of ± 1 yard can be tolerated at bout widths of this magnitude.

The performance of these machines is not significantly affected by steady winds of up to 10 mile/h when granular fertilizers are used, but strong blustery winds can obviously affect their performance. Some manufacturers provide hoods or screens but these may spoil the distribution pattern, and their use is generally limited to preventing a dust nuisance when spreading fine materials, such as basic slag, and when accurate distribution is not so essential.

The effect of variations in the granule size of the fertilizer on the distribution qualities of these machines is discussed in Section 4, but the effect of variations likely to be found in the majority of U.K. produced fertilizers, is small.

3.1 (b) *Aerial Distribution*

Fertilizer application from the air is normally done by fixed wing aircraft with a venturi distributor, designed so that the forward motion of the aircraft accelerates the particles laterally (Fig. 4).

In the U.K., aircraft are extensively used for spraying crops with insecticides but their use for applying fertilizers has been limited, and is greatest when soil conditions are unsuitable for conventional ground machines. Aircraft application of fertilizer is, however, common practice in

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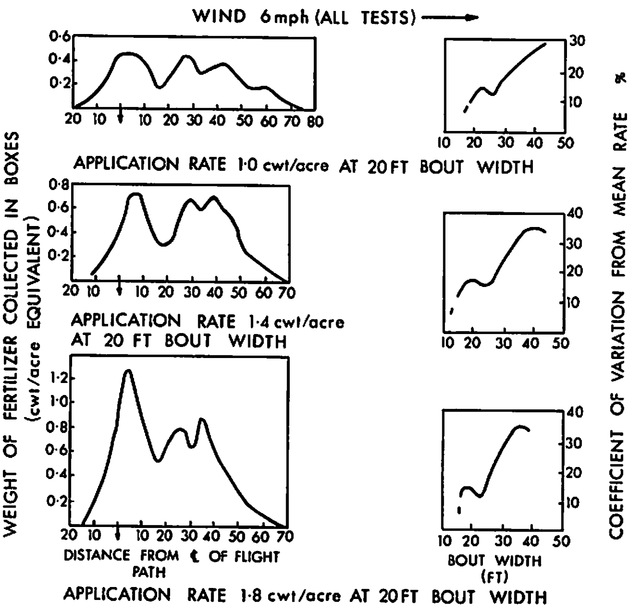
many other countries but the published test data [7 8 9] is generally based on types of fertilizers not usually used in the U.K. and on test methods which are not comparable to those used for testing land machines.

Test results, obtained by Agricultural Division, I.C.I. Limited, using a U.K. fertilizer and test methods comparable to those used for land machines, for three different versions of a venturi distributor are summarized in Figs. 5, 6 and 7. These tests were performed by flying the aircraft at a speed of 80 mile/h and at a height of

FIG. 7

TEST RESULTS FOR DISTRIBUTOR C



40 ft above a continuous line of boxes, each 2 ft by 2 ft by 2.5 ft deep and weighing the fertilizer (prilled ammonium nitrate with a median size of 1.9 mm and a size range of 1.4 to 2.8 mm) collected in each box; the depth of the boxes ensured that no fertilizer bounced in or out of them.

The unsymmetrical Transverse Distribution Patterns are due to the cross-wind and therefore when calculating the Overall Transverse Distribution Pattern, and the Coefficient of Variation obtained for different bout widths, it has been assumed that, when spreading up and down the field, the left hand side of the pattern will be superimposed on the right hand side: this is, of course, contrary to the method used for land machines when tested in ideal conditions.

Distributor A was a standard distributor. The Transverse Distribution Pattern (Fig. 5) shows two sharp peaks but if the bout widths are restricted to 20 ft, and allowing for 1 yard deviation, the Coefficient of Variation in the Overall Distribution Pattern will not exceed 15%.

Distributor B was a modified version of Distributor A. In an attempt to reduce the peaks a curved insert was fitted between the hopper feed aperture and the distributor. The two test results shown in Fig. 6, show that this was only partly successful; the Coefficient of Variation would be 15% if the bout width was 30 ft but this would increase to 20% if there was a 1 yard deviation.

Distributor C, although only slightly different from Distributor A had, in addition, a splayed air intake extension which doubled the intake area making it approximately equal to the exit area. The test results for application rates of 1.0, 1.4 and 1.8 cwt/acre indicate that the Coefficient of Variation would not exceed 15% if the bout width was 20 ft (Fig. 7).

It is not claimed that these tests are conclusive: only a limited number of tests were carried out and the modification to Distributor A, which resulted in Distributor B, was very simple. However, the tests indicate that if the characteristics of the distributors when operating under different wind conditions are accurately determined, by field tests or wind tunnel tests, and the operator is given adequate instruction then the distribution of fertilizer by aircraft can be satisfactorily achieved.

3.1 (c) *Full-Width Distributors*

Many types of full-width distributors have been marketed and many more have been patented—but for various reasons most have had a relatively short life [10 11 12]. Two types of mechanism have remained consistently popular —the Rotating Plate and Flicker and the Agitator Feed.

Published tests reports on machines with Rotating Plate and Flicker mechanisms [13 14 15 16] show that the evenness of distribution with granular fertilizers is significantly better than with powders and that, with granular fertilizers, the Coefficient of Variation in the Transverse Distribution Pattern is less than 10%. On a smooth surface the longitudinal distribution is also very good but the mechanism is sensitive to bumps, and the frequently quoted N.I.A.E. report[13], published in 1958, shows that the application rate increased to 2000% of the mean rate when the machine was driven over a 1.5 in. lump. On more modern machines the author has found, however, that the variations seldom exceed ± 30% of the mean rate and that, under average conditions, the Coefficient of Variation is about 15 to 20% for application rates of about 3 cwt/acre.

In the last few years new machines with agitator feed mechanisms have been introduced and N.I.A.E. reports have been published on two of them[17 18]. On both machines the Coefficient of Variation for the Transverse Distribution was less than 10%, when using granular fertilizer, but the quality of the longitudinal distribution depended, to a large extent, on the amount of bouncing to which the machine was subjected. The reports indicate that, with this type of machine, the increase in the application rate, due to bouncing, will only be a problem on excessively rough ground. When used in average conditions the machines will probably distribute granular fertilizer so that the Coefficient of Variation does not exceed 15%, and 10% should be attainable in many cases.

With this mechanism the fertilizer is applied in bands, approximately 6 in. apart (the usual centre distances of the feed holes). Normally this has no detrimental or visible effects, but the author did have one instance reported of scorching on grass, following a heavy nitrogenous dressing. The manufacturers' suggestion of welding a 2 in. tube about 6 in. below the holes, to scatter the fertilizer, appears to be a satisfactory and cheap solution to this problem.

A recently introduced machine has an interesting mechanism: it consists of two p.t.o. driven contra-rotating neoprene covered rollers running the full length of the hopper (Fig. 8). No test report has yet been issued but initial trials indicate that the machine may be a useful addition to the range of full width machines.

Some modern full width machines are relatively easy to clean and maintain and a number have been designed so that they can be quickly transported along narrow roads and through gates. Markers are not usually used, if the previous wheel marks can be seen, but great care is necessary to maintain a constant bout width; any error will result in a strip being either double dosed or completely missed. With some machines, especially those having a forced feed mechanism, the feed rate can vary with forward speed even though they are land wheel driven. It is essential therefore to select a forward speed on entering a field and to maintain it throughout.

3.2 Placement Machines—Combine Drills

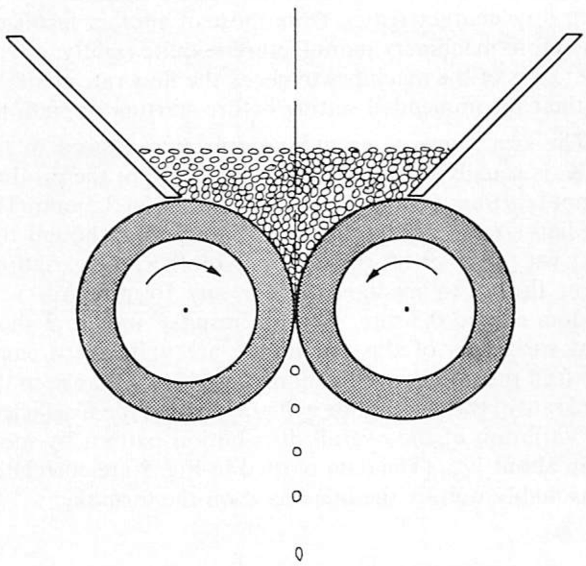
The commonest fertilizer metering mechanism for many years, was the star wheel feed, and the tests carried out by the Scottish Station of the N.I.A.E.[19], referred to by Holmes, were performed on the pre-1961 machines with this mechanism. In four of the machines the star wheels were placed horizontally on the bottom of the hopper, while in the fifth machine they rotated vertically over the orifice. In all cases an undulating pattern was obtained which was repeated in a regular cycle, corresponding to the movements of the adjacent teeth over the hopper orifice. The summarized results are:

Machine	*Approximate pitch of cycle in.*	*Coefficient of Variation (%) using different fertilizers*	
		Granular Fertilizers	*Powdered Fertilizers*
A	66	28	33
B	42	35	72
C	72	60	48
D	72	38	41
E	60	23	40

The best performance was with Machine E using granular fertilizer when the minimum and maximum rates were 67% and 145% of the mean rate. No indication is given of which of the five mechanisms was in Machine E.

FIG. 8

CONTRA-ROTATING ROLLER FEED MECHANISM



New machines have, however, been introduced, and tests carried out by the Agricultural Division, I.C.I. Limited, on modern machines with spiral agitators, peg wheels and star wheels show that the variations in feed rates do not exceed $\pm$ 33% of the mean and that a Coefficient of Variation of 10 to 15% is attained.

Combine drills, generally, have not improved to the same extent as other fertilizer applicators in recent years. Many are not easy to clean and maintain, and in some the size of the fertilizer hopper is inadequate for modern application rates. These factors have led many farmers to consider, if not to practice, broadcasting fertilizer and drilling the seed, especially when there appears to be advantages to be gained by narrow row drilling.

4. The Effect of Granular Size and Shape on the Performance of Application Machinery

The majority of the granular fertilizers produced in the U.K. are consistent in quality; they are free-flowing, the granules do not easily break down, their moisture pick up rate is relatively slow and they do not readily cake. The granules do, however, vary in size but the size range is limited and the variations in the size analysis, that are likely to occur, between one bag of fertilizer and another of the same formulation, do not significantly alter the performance of application machines.

In all application machines the fertilizer is metered by volume and the mass metering rate therefore depends on the bulk density of the fertilizer and on the shape, surface characteristics and the size of the granules. Although in any one fertilizer the chemical analysis, the shape, the

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surface characteristics and the specific gravity of the individual granules do not vary to any significant extent, the granules of one fertilizer can differ significantly, in their flow characteristics, from those of another fertilizer. Therefore machinery manufacturers, quite rightly, advise operators of the machines to check the flow rate achieved at their recommended setting before starting operations.

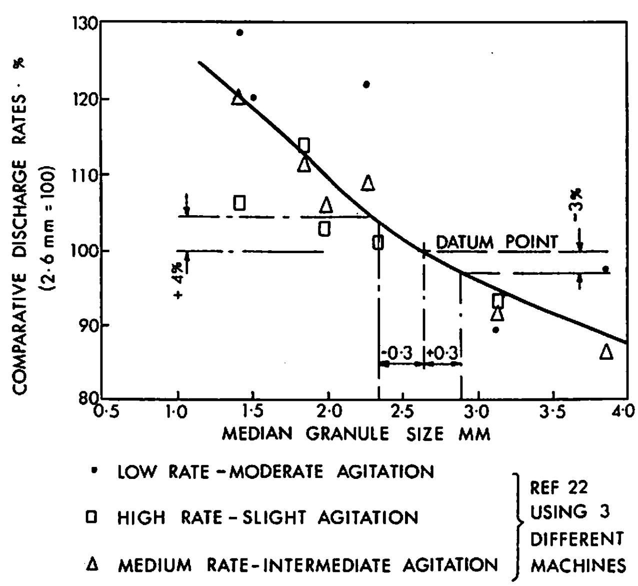
The size range of granular fertilizer produced in the U.K. is usually limited so that about 90% of the product is not less than 1.5 mm and not greater than 3.5 mm. The median size is usually about 2.5 mm and, although this may vary from one formulation to another, the variations from the mean median size for any formulation very seldom exceed 0.3 mm. The test results[20] in Fig. 9 show that variations of this magnitude are unlikely to cause the feed rate to change by more than 4%: a change in the feed rate of this magnitude will not increase the Coefficient of Variation of the overall distribution pattern by more than about 1%. (The data plotted in Fig. 9 are correlated reasonably well by the line based on the formula:

$$W = \text{Constant}\left(\frac{D}{d} - 3\right)^{0.3} \times D^{2.5}$$

where W = mass flow rate
d = particle diameter
D = orifice diameter

which is a simplified version of a formula suggested by Rose and Tanaka[21] to calculate flow rates of different materials through different sizes and shapes of orifices.)

FIG. 9
EFFECT OF CHANGE IN GRANULE SIZE ON FEED RATE



Some machines are more susceptible than others to changes in the particle size but all the published reports (Ref. 20 *et al*), based on theoretical and experimental investigations, show the variation in the performance of broadcasting distributors is not sufficient to be significant if about 90% of the granules are greater than 1.5 mm and less than about 4.0 mm. It has also been found that a rounder shape and a smoother surface to the particle may reduce the effect of particle size. This has been confirmed, to some extent, by Agricultural Division, I.C.I. Limited when spreading prilled ammonium nitrate of 1.9 mm median size. Static tests similar to those described in Section 3.1 (a), on a number of machines, showed that the spread patterns obtained were similar to those produced by the more conventional granular fertilizers with a median size about 2.5 mm. As part of this investigation a number of farmers' and contractors' machines were tested, in the field, spreading both types of fertilizers. On those machines where the position of the feed chute could be altered, relative to the disc, the chute was set according to the manufacturers' instructions for spreading granular fertilizer; when this was not well defined the best position for granular fertilizer was determined and this setting used for spreading the prilled fertilizer. These results summarized in Table 3 show that, for the machines tested, similar distribution patterns were obtained for both granular and prilled fertilizers. It must be emphasized that this work was done in 1962, that the machines used varied in age and condition and that the distribution figures were calculated using the manufacturers' recommended driving centres.

5. The Application of Blended Fertilizer

A *blended* fertilizer is a mixed fertilizer consisting of a mechanical mixture of fertilizer materials. Although the majority of granular fertilizers produced in the U.K. are compound fertilizers, consisting of granules of similar composition, a few blended fertilizers are produced.

It is of course essential that the components of a blended fertilizer do not segregate during transport, storage and when the fertilizer is being applied to the land. The manufacturing techniques to prevent segregation are well established[22] [23]*et al* —one of the most important factors is the size analysis of the different components—and investigations have been made into the amount of segregation that occurs when these fertilizers are applied by broadcasting and other distributing machines[24] *et al.* Static test methods, similar to that described in Section 3.1 (a), have generally been used and these show that, if the components are correctly matched for size, then little segregation occurs due to the spreading action of a spinning disc mechanism.

This method can be criticized because if segregation occurs in the hopper the chemical analysis, and possibly the shape, of the transverse distribution pattern would be changed. The same criticism can be made of using the standard tray tests to determine the transverse and longitudinal distribution patterns. The method adopted by the Agricultural Division, I.C.I. Limited is to carry

TABLE 3

Comparative Tests with Prilled and Granular Fertilizer on Farmers' and Contractors' Machines

	Type of Machine	*Fertilizer*	*Application Rate cwt/acre*	*Maximum Measured % Variation from mean rate*	*C. of V. % of mean rate*
Machine A	Small hopper broadcasting machine with spinning discs	Prilled	2.4	+74 —44	25
		Granular	1.9	+66 —46	30
Machine B	Small hopper broadcasting machine with spinning discs	Prilled	1.7	+51 —43	20
		Branular	1.6	+57 —37	18
Machine C	Small hopper broadcasting machine with spinning discs	Prilled	0.6	+39 —23	20
		Granular	0.8	+30 —18	17
Machine D	Small hopper broadcasting machine with spinning discs	Prilled	2.0	+59 —39	30
		Granular	1.6	+44 —37	25
Machine E	Small hopper broadcasting machine with spinning discs	Prilled	1.5	+33 —39	20
		Granular	1.3	+30 —35	20
Machine F	Small hopper broadcasting machine with spinning discs	Prilled	0.5	+73 —37	20
		Granular	0.5	+68 —44	23
Machine G	Small hopper broadcasting machine with spinning discs	Prilled	1.5	+46 —53	30
		Granular	1.6	+60 —55	33
Machine H	Small hopper broadcasting machine with oscillating spout	Prilled	1.3	+28 —59	13
		Granular	1.4	+30 —60	13
Machine I	Large hopper broadcasting machine with spinning disc	Prilled	1.8	+13 —15	5
		Granular	2.0	+21 —24	9
Machine J	Large hopper broadcasting machine with spinning disc	Prilled	1.3	+56 —23	18
		Granular	1.4	+65 —29	20

out 'Random Pattern' tests to confirm the initial results given by static and conventional tray tests.

In the Random Pattern tests, about 100 boxes, each measuring 30 in. × 12 in. × 3 in. and containing egg box partitions to prevent fertilizer bouncing out, are positioned on an area of about 250 ft by 50 ft. The same layout is used for each test, and the boxes are arranged so that every foot strip across the pattern (except the gaps for the wheels) is covered by at least 3 boxes. The positions of the boxes along the patterns were randomly chosen. When a broadcasting machine is being tested with a blend it is loaded with fertilizer and driven at about 5 mile/h.

(a) up one side of the test area
(b) over rough ground
(c) down the centre of the test area
(d) over rough ground—and finally
(e) up the other side of the test area.

The whole operation is timed so that the machine starts with a full hopper and finishes with at least three-quarters of the hopper emptied. By weighing and analysing the fertilizer collected in each box, the actual achieved distribution is measured.

A summary of the results obtained when spreading 73:27 (25:0:16 N.P.K.) blends of prilled ammonium nitrate and potassium chloride are shown in Table 4, together with the distribution obtained using a conventional compound granular fertilizer.

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TABLE 4

Results of Random Pattern Tests using a small hopper capacity spinning disc broadcaster with 25:0:16 blends consisting of 1.5-3.0 mm prilled ammonium nitrate and potassium chloride

	Size Range of KCl mm	*% of area where rate is within ± 33% of Mean Rate*		
		Total	*N^2*	*K^2O*
Blend 1	0—4.4	90	91	73
Blend 2	1.5—4.4	95	95	82
Blend 3	1.5—3.0	85	83	82
Blend 4	1.5—3.5	94	95	93
Granular Compound	1.5—3.5	97		

The table shows that:

Blend 1—contains the widest size range of potash. The overall distribution is not as even as that for granular fertilizer and there is some evidence of segregation.

Blend 2—potash size range 1.5—4.4 mm. This has a better total distribution than Blend 1 and the amount of segregation is smaller.

Blend 3—the potash in this blend has the smallest size range, i.e. 1.5—3.0 mm., but although there is negligible segregation it gives the worst distribution pattern.

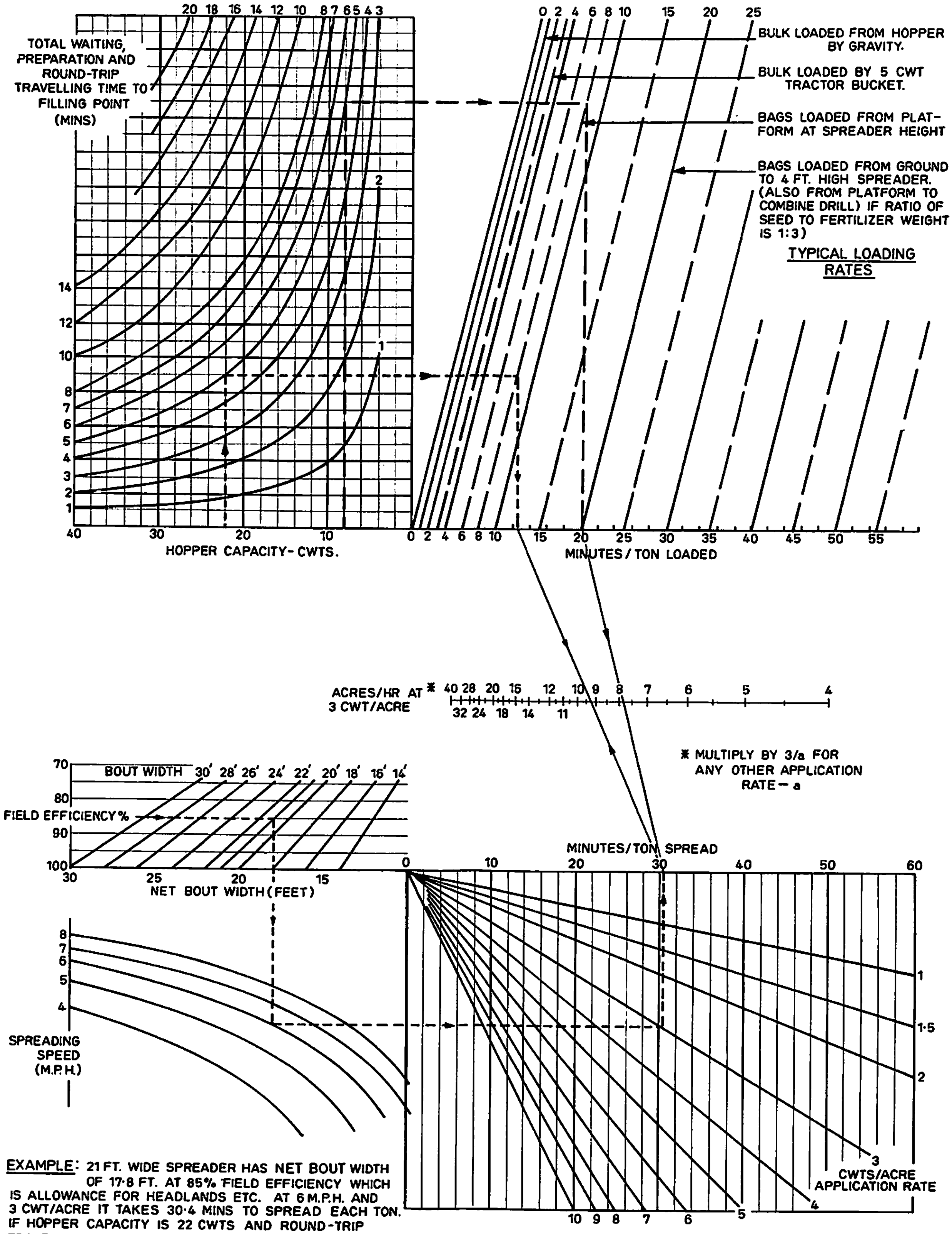
Blend 4—potash size range 1.5—3.5 mm. The total distribution is very close to that obtained by compound granular fertilizer and there is negligible segregation.

A number of farmers' and contractors' machines, in an 'as found' condition, were tested using the conventional tray methods when distributing the blend and a conventional compound granular fertilizer. The overall distribution patterns for the broadcasting machines were calculated assuming that the machines would be driven at the manufacturers' recommended bout widths. In each test the fertilizer collected in each box was weighed and analysed. The results, summarized in Table 5, show that the N^2 and K^2O nutrients in the blend were distributed as evenly as those of a compound granular fertilizer by most of the machines tested.

TABLE 5

Test Results for Different Machines Spreading a Blended and a Compound Granular Fertilizer

	Type	*Material*	*Coefficient of Variation % of Mean Application Rate*	
			Transverse	*Longitudinal*
Machine A	Small hopper broadcasting with spinning disc	Blend N^2 K^2O	15 15 10	
		Compound	10	
B	Small hopper broadcasting with spinning disc	Blend N^2 K^2O	15 16 15	Not Measured
		Compound	15	
C	Small hopper broadcasting with oscillating spout	Blend N^2 K^2O	10 10 10	
		Compound	10	
D	Large hopper broadcasting with spinning disc	Blend N^2 K^2O	11 11 10	3 3 4
		Compound	15	3
E	Full width-rotating plate and flicker	Blend N^2 K^2O	15 15 15	16 15 13
		Compound	15	14
F	Full width—reciprocating plates	Blend N^2 K^2O	Not Measured	23 20 30
		Compound	Not Measured	19



EXAMPLE: 21 FT. WIDE SPREADER HAS NET BOUT WIDTH OF 17·8 FT. AT 85% FIELD EFFICIENCY WHICH IS ALLOWANCE FOR HEADLANDS ETC. AT 6 M.P.H. AND 3 CWT/ACRE IT TAKES 30·4 MINS TO SPREAD EACH TON. IF HOPPER CAPACITY IS 22 CWTS AND ROUND-TRIP TRAVELLING TIME IS 5 MINS. THEN AT A FILLING RATE OF 8 MINS/TON LOADING AND TRAVELLING TAKES 12·5 MINS./TON. UNDER THESE CONDITIONS 9·4 ACRES/HR CAN BE COVERED. IF HOPPER CAPACITY IS 8 CWT 8 ACRES/HR CAN BE COVERED.

FIG. 10 'READY-RECKONER' NOMOGRAPH FOR SOLID FERTILIZER APPLICATION MACHINERY

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6. The Cost of Applying Solid Fertilizers

The cost to the farmer of applying fertilizer consists of the labour costs of handling the fertilizer and applying it, and the operating and overhead costs of any equipment, including storage facilities, that he uses.

The best handling and application method cannot, however, be decided on cost only. The convenience of the system and the fact that fertilizer must frequently be applied in a relatively short time, and fitted in with other operations, must be taken into account.

The 'Ready Reckoner' Nomograph for fertilizer applicator performance Fig. 10 (based on data from Ref. 25), is a convenient method of determining the acres/hour likely to be achieved by a fertilizer applicator, but the operating costs of applying fertilizer are relatively small compared to the overhead costs. Although the nomograph indicates that a machine of 22 cwt hopper capacity will achieve about 9.5 acres/hour and that a machine of 8 cwt capacity will achieve about 8 acres/hour (both using the same method of filling, the same forward speed and the same bout width), the total cost per ton could be increased by 20s. or 30s., or by 2s.-3s./acre for 3 cwt/acre application rates, using the larger and more expensive machine if the annual fertilizer tonnage is small.

It cannot be over-emphasized that good and poor management of the whole handling and application operation can result in total cost differences in the order of 6s. per ton of fertilizer. It is, for example, sensible to store fertilizer in the most accessible position; multiple handling should be avoided; the storage of bags above the ground is advisable and a platform 3 to 4 ft high and costing no more than £1 per ton capacity facilitates hopper filling and can be easily justified economically.

Because of the large number of significant variables affecting the cost to the farmer of handling and applying fertilizers, it is impossible to summarize these costs with any degree of accuracy. However, Fig. 11 indicates the magnitude of these costs when the average application rate is 3 cwt/acre and illustrates how, because of the overhead costs, they decrease with increasing annual tonnage.

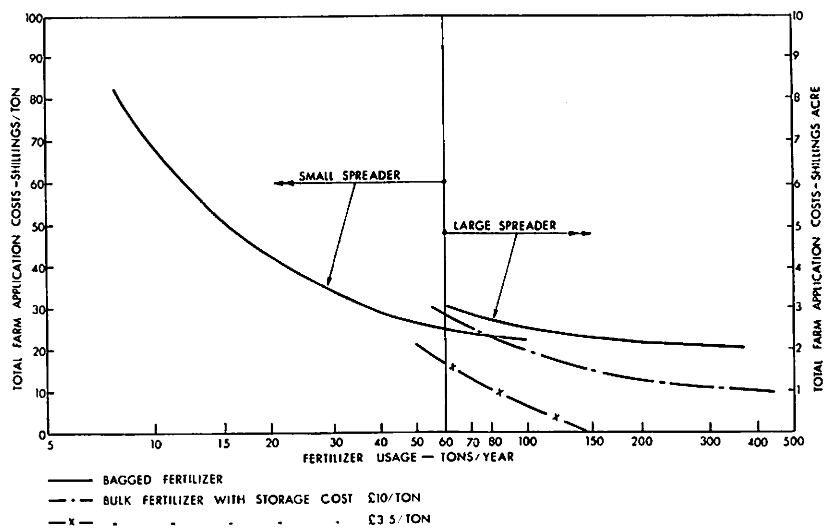

FIG. 11 TOTAL NET FARM COSTS FOR HANDLING AND APPLYING SOLID FERTILIZER
(BASED ON AN APPLICATION RATE OF 3cwt/acre)

In preparing this data appropriate rates of interest, depreciation and maintenance have been used, amounting to about 25% and 10% per annum for machines and buildings respectively. Labour rates have been taken at 7s. per hour and in each case it has been assumed that farm storage capacity is half the annual usage. The costs when the fertilizer is stored in bulk have been based on the current bulk allowances given by fertilizer manufacturers in the U.K. It has also been assumed that:

(a) Farmers using up to 50 tons per annum will concentrate upon keeping their capital costs as low as possible, and that to achieve this they will use the lowest cost machines available capable of giving the required accuracy and evenness of distribution.

(b) To farmers using 50-120 tons per annum, a spreader with a large capacity hopper will be attractive because of the increased working rate and because the range of working from the filling point can be increased at an increased total cost of about 4s. per ton.

At this level of fertilizer usage bulk fertilizer starts to look attractive, but it may be that the problems and costs of either storing high analysis fertilizers or using low analysis compounds will outweigh any advantages.

(c) Farmers using in excess of 120 tons per annum will require a high rate of working and reduced handling at a reasonable cost. A large hopper capacity machine is a definite advantage and bulk fertilizer becomes attractive.

Conclusion

The demand of farmers and contractors for reliable machines capable of applying solid fertilizer accurately, quickly and easily has resulted in many new machines being introduced in recent years so that there is now a wide range of machines available, from which any user can choose a machine suited for his needs, capable of applying solid fertilizer to the required agronomic standards.

The improvement in the design, quality and performance of these machines is due to the efforts of the designers and manufacturers but the majority of them will probably agree that the rate of improvement has been accelerated because of the close co-operation between them, the agronomists and the fertilizer manufacturers, because of research at British and foreign universities on the principles of distributing fertilizer, because of the National Institute of Agricultural Engineering (N.I.A.E.) testing machines and publishing Users' Test Reports and, perhaps the greatest factor, because farmers and operators of the machines have been prepared to accept new techniques and new methods. If this co-operation continues between all who are responsible for solid fertilizer being correctly applied, the benefits to the farming industry can be considerable. There is every indication that it will continue and if this paper has contributed anything to furthering it the author's object will have been achieved.

Acknowledgements

The author wishes to thank the directors of Agricultural Division, I.C.I. Limited, for permitting the publication and presentation of this paper, and his colleagues for their advice and assistance, especially Mr K. W. MacKenzie who carried out the test work. The author would also like to thank the many manufacturers, farmers and contractors who have provided machines for testing and who have been so co-operative and helpful and the staff of the N.I.A.E. for their invaluable work.

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ACHIEVING THE REQUIRED DISTRIBUTION OF LIQUID NUTRIENT SOURCES

by

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Presented at the Spring National Meeting of the Institution in the Farm School, Milton, Cambridge Thursday, 28 March 1968

INTRODUCTION

While the performance of many distributors of solid fertilizers has been measured, there is relatively little information of the accuracy of distribution of fertilizers in solution. On the other hand the accuracy of placement of plant protection and weed killing chemicals has been the subject of study and both the source of errors and the likely limits of accuracy are beginning to be established. It is not the object of this paper to assess what is being achieved in the way of liquid fertilizer distribution, but rather, on the basis of what is known about spray application in general, to assess the potential performance of this method particularly in the context of the fertilizer requirements set out by Holmes.[1]

To make this approach it is necessary to distinguish between factors such as tractor speed and liquid pressure setting, where results from one type of application can readily be applied to another, and errors due to variable distribution across a swath—where the measurement must be related to the required biological response. In particular, Holmes suggests that the relevant unit of area to be taken as a nutrient source is of the order of one or two square feet, whereas in crop protection it is of the order of square inches.

It is also necessary to bear in mind that errors in application arise not only on the foot to foot scale, but also from bout to bout, field to field, and day to day. It is necessary, therefore, to consider the various components of error and their likely occurrence and magnitude, before considering the demands of fertilizer requirements upon application equipment and the possibilities of meeting them.

SOURCES OF ERROR

In the conventional method of applying liquids by mobile sprayer the application rate is dependent upon supplying liquid through fixed orifices at a given pressure and travelling over the ground at a desired speed. It is normal for machinery manufacturers to give tables of driving speeds and pressures to give a desired application rate but errors can arise in setting both.

PRESSURE

Errors in pressure setting can arise either from a faulty gauge indication or from pressure losses between gauge and nozzle. The average error in indication on a random sample of 25 farm sprayers making herbicide applications was 24%.[2] The output will vary almost as the square of the pressure so that this would represent an average error of about 12% in application rate. This was predominantly gauge error, rather than pressure loss, since the average boom pressure was close to the average indicated pressure. Since these were generally low volume treatments the absence of serious pressure losses is not surprising but spraying machines tested at the National Institute of Agricultural Engineering have shown considerable pressure losses both from the control valve to the boom and along the boom when the larger nozzles supplied with them were used.[3]

TRAVELLING SPEED

Speed errors are more complicated to assess. The tractor engine speed indicator may be in error in the same way as the pressure gauge, though the errors are not likely to be so large, since the instrument is more suited to its environment than are most pressure gauges when operating in contact with agricultural chemicals. Whereas fixed errors in both types of instrument can be allowed for by a suitable calibration of machine output at the beginning of a season, gradual changes in the indications of these instruments may go unnoticed. Errors due to variations in wheel slip cannot be compensated for. These may come about as a result of changes in ground condition and especially in conjunction with work on sloping ground. In this latter case the operator can, at best, compensate for the change in engine speed from the change in loading. If he leaves it to the engine governor to control the speed there will be the additional error due to the limits of this control. He can reasonably expect to keep the engine speed within about $\pm$ 2% of a required setting, although this depends on the tractor governor and tachometer being in good condition. At present there is little information on the amount of wheel slip to be expected in a tractor in the traction conditions associated with fertilizer application.

OVERLAP

Mis-matching of swaths will result in an overdose or underdose on a proportion of the treated area nominally either doubling the dose or leaving it untreated. In the case of the survey already cited of farm use on cereals with machines with 20-30 ft boom lengths and using the drills as a guide, there was a root mean square error in overlap of 6% in 22 machines, 15 of these giving a mean overlap of 6% and the remaining 7 giving a mean gap of 5% of the swath width.

*National Institute of Agricultural Engineering

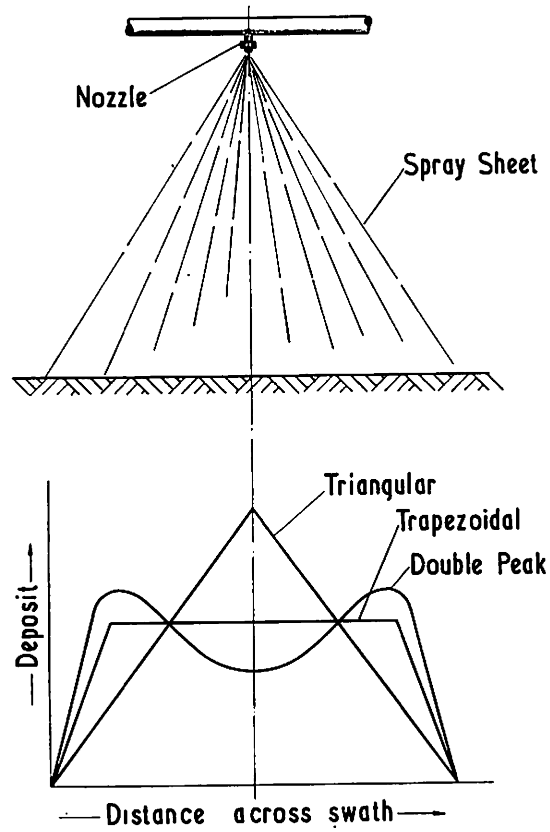
NOZZLE TO NOZZLE VARIATION

The spacing of nozzles along the boom of conventional sprayers, most often 18 in. is commensurate with the distance over which variations are significant for fertilizer response. The most important variations across the swath will therefore arise (i) from differences in output between individual nozzles and (ii) from overlapping of patterns such that there is a systematic difference in deposit between the area under the centre of a nozzle and the region where two nozzles overlap. Variations in individual nozzle outputs are of considerable significance in low volume pesticide application but as nozzle size increases the variation tends to decrease, particularly in machined nozzles (Table 1). The standard of manufacture and selection of any set of nozzles can change the level of variation several-fold, but, whereas a 3% coefficient of variation is difficult to achieve in nozzles designed to apply 10 gallons per acre, it is achieved in practice by the larger crop spraying nozzles at volumes approaching those required for fertilizer application. It follows that well made metal or ceramic-tipped nozzles for application rates of 30 to 100 gallons per acre should be capable of coefficients of variations not exceeding 2.5%.

In practice, to date, we have a variety of special nozzles being used for fertilizer application and there is too little information on their performance for any generalization. There are, however, two factors which could modify these conclusions drawn from knowledge of high volume spray nozzles. Because of the corrosion problem in handling fertilizers, nozzles made by moulding plastics have appeared attractive as a cheaper alternative to machining stainless steel. What limited evidence there is on the performance of plastic nozzles already in use indicates that the throughput of such nozzles is more variable than either the metal or ceramic nozzles at present used. On the other hand because the requirements for high volume application and particularly for fertilizer distribution have generally been conceived to be less stringent than for low volume application of crop protection chemicals, it is very likely that we have not seen larger nozzles produced to as high a standard as is economically desirable.

In the matter of overlap of nozzles we have a similar picture. The use of high volumes of coarse spray should allow more accurate distribution and greater overlapping of the output from adjacent nozzles, either by increased boom height or by rearward trajectory of spray from the boom. This has been exploited by some applicators to improve uniformity, but more generally the advantages in this respect seem to have been offset by using nozzles which do not give individual distributions particularly suitable for evenness when overlapped.

Fig. 1 Theoretical Nozzle Deposit Patterns



The volume of liquid collected on strips running parallel to the direction of travel may be measured and plotted as a histogram against position across the swath. This may be done accurately in troughs as laid down in the British Standard (BS.2968) or approximately, because of splash and bounce of drops, by spraying on to corrugated sheet running along the line of travel. While the niceties of distribution from inch to inch do not concern us in fertilizer application, it is as well to consider the basic form of distribution from the type of nozzle in use at a particular height and orientation. Generally this may be triangular, trapezoidal or have a double peak (Fig. 1). Large hollow cone swirl nozzles typically give this last pattern. Also deflector nozzles or other fan nozzles without a shaped orifice may give peaks at the edge of the

TABLE 1

Variation in nozzle throughput in commonly used spray nozzles

	Type A (metal fan)			*Type B (ceramic fan)*				*Type C (metal swirl)*		
Mean Output gal/h	7.4	14.1	27.1	4.4	9.0	12.5	16.8	11.7	21.6	31.4
Coefficient of variation, %	7.2	3.7	2.0	4.1	2.2	2.1	3.8	6.7	2.1	2.1

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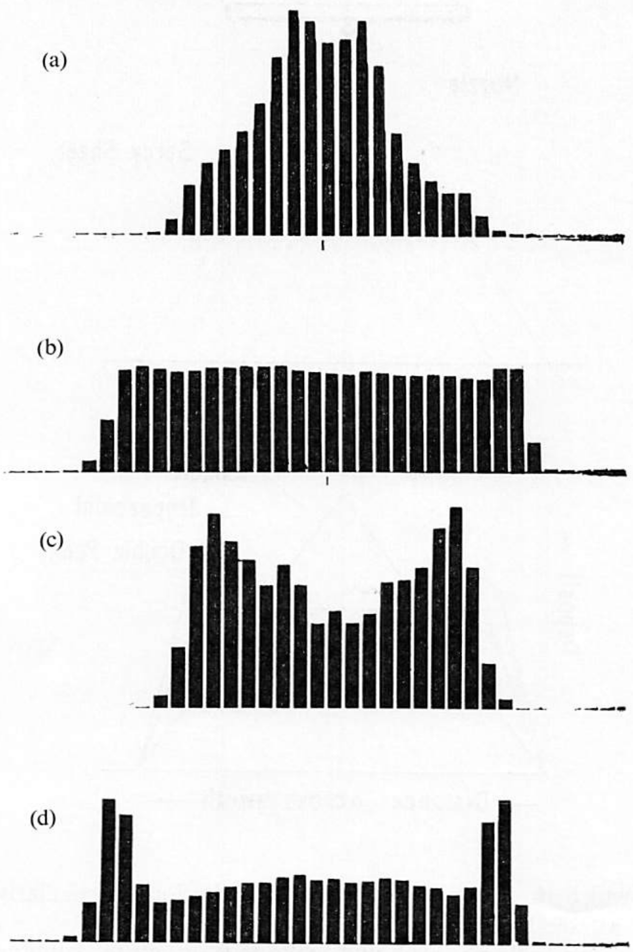

Fig. 2. Across-swath distribution from typical nozzles:

(a) Fan nozzle — triangular,
(b) Fan nozzle — rectangular,
(c) Cone nozzle,
(d) Deflector nozzle.

sheet (Fig. 2c and d). When triangular or trapezoidal patterns are overlapped the distribution can be theoretically uniform if the extreme of one fan of spray extends to the centre line, in the first case, or in the trapezoidal case to the limit of the plateau of the next nozzle pattern. Decreases in overlap can lead to serious underdosing at the junction, but above the theoretical limit the distribution is not seriously affected by small additional overlapping. With swirl and deflector nozzles one can get cases where peaks from adjacent nozzles coincide. Taking an average pattern from a set of swirl nozzles of this type, as shown in Fig. 2c, spaced at 18 in. but at such a height that the peaks coincide, the difference in dose between 9 in. bands centred under a nozzle and that in between will be about plus and minus 38% of the mean. A reduction of overlap by about 5 in. can reduce this to $\pm$ 15%. If one foot wide strips are taken, the variation, if the strips are centred on alternate nozzles, will be greater than between 9 in. ones. On the other hand, of course, when 18 in. widths are taken the variation disappears. This indicates that with nozzles of this kind one can expect considerable variations across the swath at the same pitch as the nozzles and that although this may be on too small a scale to influence crop response, any variation of this sort will show up markedly on any sample area appreciably smaller than the nozzle spacing dimension.

REDISTRIBUTION OF SPRAY BY WIND AND ERRATIC BOOM MOVEMENT

To the variation of deposit from the sprayer in ideal conditions of still air and regular boom movement, must be added those due to field conditions. Predominant in this will be the effects of gusty wind and random oscillation of booms relative to the tractor. While no single figure can be ascribed to the size of this variation and it obviously depends very much on ground and weather conditions, the possible order of it may be gathered from a measurement of deposit made along the path of individual nozzles in the course of a spring cereal spraying operation.

Results so far available from this source suggest that when a square foot is taken for the sample area, the variation will have a coefficient of about 10% to 25% depending upon machine and conditions. It is to be expected that the use of coarser sprays will help to reduce this variation because the drops will be less subject to wind condition, and the only two sets of data available relating to low pressure nozzles do show variations towards the lower end of this range. When more data is available it will be possible to apportion this variation between boom and wind movement, and to relate the wind effects to drop size, nozzle height and orientation and wind level, but this is not yet possible.

TOTAL ERROR

The errors in total output per acre, in matching swaths and in nozzle overlapping, may be systematic and may vary with the time from calibration of the machine, or from field to field, and with operator's skill. Nozzle to nozzle variation is more nearly random and fixed by nozzle quality. The effect of wind and boom movement is more or less random in position but dependent on field to field and day to day conditions. In addition, we have systematic errors (on an unknown scale) due to uphill and downhill wheel slip where hilly conditions are encountered. It is obviously not possible to add up these different sorts of variation to give an overall figure for comparison with the set requirements of 10% to 15 % coefficient of variation. Also the variation measurement may be very sensitive to the size of the unit area as this changes from wider to narrower than the nozzle spacing. It is only possible, therefore, to review the factors considered above to see what is the best that might be done in terms of operation and machine design to reduce them and then to consider how the residual variation might line up with the agronomic requirements or compare with solid distributors.

OPERATIONAL LIMITS

The major part of the day to day variation can be eliminated by keeping a check on the actual amounts used on each field and re-calibrating output as soon as there is a suspicion that indications are incorrect. Other factors affecting total output like the build-up of pressure losses due to filter blockage and undue changes due to worn nozzles will also be watched for and avoided by a competent operator. Errors in matching swaths can also be greatly reduced if an operator takes care and measures or uses a guide for, rather than estimates, his position after turning.

Whereas the average error in application rate on the farm sprayer survey already referred to was 16%, an examination of records from a series of experiments shows that in ideal conditions (making repeated application to the same areas in level grass orchards) experimental staff of the N.I.A.E., taking every care with application rate, were able to apply volumes that were always correct within 10% and the average error in 28 applications at 50 gallons per acre was about 2%. While there is no comparable evidence for arable treatments, it seems likely that a skilled farm operator could be expected to achieve an average overall error of not more than 5%.

SMALL SCALE VARIATIONS

Superimposed on the variation in the 'per acre' dose will be the small scale variations due to wind, to fluctuations in tractor speed and boom oscillation, and to differences between individual nozzles and errors in their overlapped pattern. It is evident that the first two will be large compared with nozzle to nozzle variation if good nozzles are used. Nevertheless, since the final variation is evidently going to be of an order of magnitude shown by Holmes to be significant, there is an economic case for reducing it wherever possible. It is evident that nozzles should be selected which have a coefficient of variation of output of not more than 2% or 3%. They should also give a combined pattern across the swath without the large peaks and troughs associated with hollow cone and deflector nozzles unless the nozzles are close enough on the boom for it to be certain that individual plants do not detect this variation.

It remains only to assess the size of the variation introduced by the field conditions. From the results given it can obviously be large from square foot to square foot, even with a coarse spray. At present, there is too little evidence as to the causes to say how far it can be affected by boom and nozzle design and how far it is dependent upon wind and soil conditions which cannot be controlled. It can obviously be considerably reduced by a study of the problem and the use of nozzle and boom arrangements designed to reduce this variation.

CONCLUSIONS

A conventional high volume sprayer fitted with nozzles to give a coarse spray is likely to fall short of the accuracy of distribution required by the agronomist. While the performance of equipment now in use for liquid fertilizer application is not known, it seems very unlikely from the evidence on crop spraying that this requirement is being met.

A machine suitably designed, e.g. with pump and nozzles not subject to rapid wear, and used by a competent operator should make an overall application within about 5% of nominal, but this variation must be allowed for before considering small scale variations.

Nozzle variations will be within acceptable limits if good quality nozzles of suitable design are used.

Work is needed on the effect of wind on the re-distribution of liquid from a boom, and on boom design, to enable variations in the field to be reduced to acceptable limits.

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THE APPLICATION OF FERTILIZERS IN AGRICULTURE

THE FORMS AND AMOUNTS OF FERTILIZERS USED IN U.K. AND POSSIBLE CHANGES THAT MAY AFFECT METHODS OF APPLICATION

by

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Presented at the Spring National Meeting of the Institution in the Farm School, Milton, Cambridge, Thursday, 28 March 1968

INTRODUCTION

Forecasts of developments in fertilizers and their uses must take account of the causes of past changes, of technical developments in fertilizer manufacture and agriculture, and of the speed with which new information is applied by farmers. All change in agriculture depends on costs and prices and I have assumed these will be stable; large changes in the ratio of price of fertilizer to value of farm produce will alter manuring.

Forms

Possible changes in the *forms* of fertilizers produced are difficult to forecast as they may depend on research and development that is often revealed only when new processes are about to be introduced. Experiments have already tested materials that are almost as highly concentrated as is possible. Ammonia gas, now being sold to farmers in U.K., contains 83% N. Experiments in New Zealand[1] have shown that red phosphorus (100% P or 229% P_2O_5) can be used as a fertilizer; in English experiments[2] phosphine PH_3 91% P or 209% P_2O_5 was a satisfactory fertiliser. But phosphorus is a dangerous substance, phosphine is a spontaneously inflammable and poisonous gas and agricultural engineers would find either difficult to handle. The most concentrated sources of phosphorus and potassium that have been tested are potassium polyphosphates[3] (some have 23% P and 32% K—approaching 100% $P_2O_5+K_2O$).

Most change in the *forms* of fertilizers used in the next 10-20 years is likely to be improved physical condition and increased concentration of materials we now know. Changes in the chemical nature of common fertilizers are more speculative. New 'slow-release' fertilizers that fit nutrient supplies more closely to the needs of crops may be developed, but research already done has failed to find substances that are much more efficient than ordinary fertilizers for agricultural crops.

Amounts

Changes in the amounts and kinds of fertilizers used in U.K. are reviewed each year by the Fertilizer Manufacturers' Association (F.M.A.)[4]. The Surveys of Fertilizer Practice made by N.A.A.S. and F.M.A. in collaboration with Rothamsted[5] show how farmers use the fertilizers they buy. Both surveys are used here in discussing why fertilizer use changes, and for forecasting future trends.

Field experiments show how much fertilizer is justified for individual crops on the soils and with the farming methods used in the experiments. Laboratory research, and information about soils, show how to extend the results of experiments on a few sites to other soils. Experiments involving different kinds of farming help to allow for differences in farming system in planning fertilizing. When all of these different kinds of information about fertilizer use are considered together with crop and fertilizer prices, 'optimum' dressings for individual farmer's fields may be worked out in the way shown by a N.A.A.S. publication.[6] Achieving these optima depends on economic conditions in agriculture, on how quickly information about fertilizing spreads, and on the success of each farmer in solving the technical and management problems involved in buying and using more fertiliser and in dealing with the extra yields produced.

Application

Farming conditions, and the physical and chemical forms in which fertilizers are sold, determine what application equipment is needed. The problems that future changes in fertilizing may cause for implement manufacturers are discussed in several sections of this paper. None that I foresee is completely new. The main need is for improvements to the kinds of equipment we already have for solids, and for machines that make the best use of the properties of liquids. Probably the manufacturers' real problem is to get farmers to pay enough for more sophisticated machines that apply fertilizers accurately and evenly, and in special places.

RECENT CHANGES IN THE FERTILIZERS USED IN U.K.

Changes in total amounts used, 1913-1967

Fig. 1 shows how much N, P and K have been used during the last 55 years. The first fertilizers supplied mainly phosphate and nitrogen. A century ago we used 30,000 tons of N, 40,000 tons of P and only 3,000 tons of K. By 1913 the P used had doubled, much more K was used, but the N used was unchanged—probably because it was expensive compared with the other nutrients. By 1939 equal weights of N, P and K were used and these proportions were maintained until 1948, when pre-war use

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had doubled. Since 1948 there has been only a slight increase in the P used; the amounts of N and K used increased similarly for ten more years, but during the last nine years the nitrogen used has more than doubled while potassium has increased by only a fifth.

Much of the recent increase in N used has been on grassland and cereals. The discussion later suggests this increase is likely to continue on grass; there are also sound reasons for using much more P and K on grass, and some increase in the N and K for cereals is also justified. If farming remains at least as profitable as at present, by 1978 British farmers may use 1 million tons of N, and rather more P and K than at present.

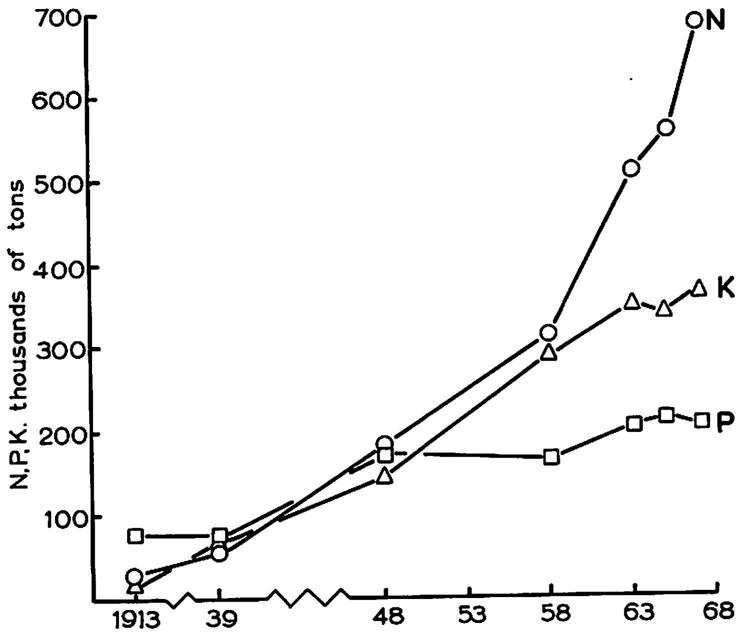

Fig. 1. Changes in fertilizers used in the United Kingdom, 1913 to 1967.

Changes in proportions of straight and compound fertilizers

Compound fertilizers ('mixed' fertilizers containing two or three nutrients) have long been important in U.K. and thirty years ago they supplied about half of the N, P and K used. During the last fifteen years the amounts sold of 'straight' fertilizers (containing only one nutrient) have diminished (Table 1); now only a third of the N is sold straight and a little of the K[4]. Very few farmers now mix their own fertilizers, while 20-30 years ago many did. No water-soluble phosphates are used as straight fertilizers, but three-quarters of all the water-insoluble phosphate is sold 'straight' as basic slag (Table 2).

TABLE 1

Percentages of total fertilizers sold in compounds in U.K.

	N	P (soluble)	P (insoluble)	K
1952/5	55	82	25	85
1959	63	91	23	85
1963	63	96	19	92
1967	64	98	23	92

TABLE 2

Basic slag used in U.K.

	Thousands of tons of P	*Per cent of total P*
1958	44	26
1964	56	27
1967	40	20

Compound fertilizers have become more popular since most have been granulated (roughly 20 years), because granules are easy to handle and spread. Previously most straight fertilizers were damp powders that were difficult to handle. Compounds save labour and can often supply all the nutrients recommended for the crop.

It is difficult to foresee *large* changes in the proportions of straight and compound fertilizers used in solid forms. More of the P and K fertilizers may be applied to the better soils in winter, and more of the N used as a straight top-dressing or placed beside crops grown in wide rows.

Changes in fertilizer materials and in concentration

Twenty years ago some British fertilizers were granulated and were based on ammonium phosphate, but most were made from ammonium sulphate (21% N), ordinary superphosphate (18% P_2O_5) and potassium chloride (50% K_2O). Now much of the N and P is supplied by ammonium nitrate (34% N) and ammonium phosphate (11% N + 48% P_2O_5); 'triple' superphosphate (48% P_2O_5) and some urea (46% N) are also used. There are no recent statements of the amounts of different kinds of fertilizer materials made in U.K. and I can only describe trends qualitatively.

Changes in the forms of fertilizers used have increased the percentages of plant nutrients in compound fertilizers, as shown in Table 3. Decreasing the bulk to be handled

TABLE 3

Changes in concentration of compound fertilizers

	Percentage of				
	N	P_2O_5 (soluble)	P_2O_5 (insoluble)	K_2O	$N+P_2O_5+K_2O$
1952/5	6.7	8.6	1.8	10.6	27.7
1959	8.4	9.4	1.3	13.3	32.4
1963	11.3	10.1	1.0	13.5	35.9
1967	14.7	11.0	1.0	13.6	40.4

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THE FORMS AND AMOUNTS OF FERTILIZERS USED IN U.K. AND POSSIBLE CHANGES THAT MAY AFFECT METHODS OF APPLICATION—

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cheapens costs of handling and of bags, and lessens the work in spreading.

Many compound fertilizers are nearly as concentrated as is possible from the materials used to make them. The trend for *average* concentration to increase will, no doubt, continue. Less ammonium sulphate and more ammonium nitrate and urea will be made. Ammonium phosphates will replace more of the single and triple superphosphate now used. If polyphosphates are used instead of orthophosphates, concentrations may increase still further but this change seems unlikely during the next 10 years. (Polyphosphates have to be hydrolysed to orthophosphates before they can be taken up by plants and they cannot be valued by the chemical tests now used.)

Changes in the forms of fertilizers produced in the world as a whole, published by F.A.O.,[7] are shown in

TABLE 4

Changes in the forms of nitrogen fertilizers used in the world (Source, FAO)

	1954	1960	1965
	Percentage of total N used		
Ammonium sulphate	31	26	18
Ammonium nitrate	23	28	29
Calcium nitrate	6	5	3
Sodium nitrate	5	3	2
Cyanamide	6	3	2
Urea	—	6	11
Other forms			
Solids	8	11	15
Solutions	14	18	20

Table 4. In 11 years from 1954 ammonium sulphate was displaced by ammonium nitrate as the most important N fertilizer. Calcium and sodium nitrates became less important and by 1965 urea provided over one-tenth of the world's nitrogen. Corresponding changes are thought to have occurred in the U.K. Replacing ammonium sulphate (21%) by ammonium nitrate (34% N) makes no problems, but using more urea may do. Urea hydrolyses rapidly in soil and the ammonia released may damage germinating seedlings or be lost to the air when the fertilizer is on, or near, the soil surface.[8] Damage to seedlings can be avoided by mixing the fertilizer with much soil, or placing in a band beside but not with the seed. Loss of ammonia is most serious on sandy and alkaline soils and to avoid this straight urea must be well buried; one way of doing this may be to apply a solution that penetrates into soil.

Corresponding changes in forms of phosphate used cause no application problems. In the last 15 years ordinary superphosphate became less important, and concentrated (or triple) superphosphate more important. Basic slag supplies remained roughly constant. Other changes are not shown separately by F.A.O., and no useful figures are published for the U.K. The proportion of nitrophosphates used has increased; these fertilizers are made by treating rock phosphate with nitric instead of sulphuric acid. The amount of ammonium phosphate made has also increased greatly. In the U.K. phosphate is evaluated by its water-solubility (basic slag by its solubility in citric acid solution) and we have no ammonium citrate test for evaluating water-insoluble phosphates such as the nitrophosphates and ammoniated superphosphates produced in other countries. If the cost of sulphur and sulphuric acid continues to increase, nitrophosphates and ammoniated products may be made in Britain. Our experiments have shown that they are satisfactory fertilizers provided they have half or more of their P in water-soluble form.[9] They are well granulated, stable fertilizers and are easy to apply.

Changes in types of compound fertilizers

Before 1939, compound fertilizers were mostly rich in phosphate and poor in potassium and nitrogen. Experiments showed that much more nitrogen should be used; therefore during the War and for some years after, the compositions of the mixed fertilizers that could be made were regulated. Three main types were important:

High K : 7% N, 3% P, 9% K

High N : 9% N, 3% P, 4% K

High P : 6% N, 5% P.

After restrictions ceased about 1950 many hundreds of compounds were made but the most important were 'High-K' types. These were intended for potatoes and sugar beet, but were used for many crops. This tendency continued until about 10 years ago when 'High-N' mixed fertilizers were introduced. Table 5 shows large changes in the kinds of mixed fertilizers produced. Five years ago more than 40% of compounds were rich in K (about 12% N, 5% P, 15% K), now more than 40% are rich in N (about 20% N, 4% P and 8% K). These changes have been made so that a single dressing of compound fertilizer can supply enough N for cereals, for grass and for animal feed crops (e.g. kale); they have been responsible for the amount of K used changing little in the last few years while N has increased greatly. There is little reason to expect further dramatic changes in the types of compounds used, but the total numbers offered to British farmers may diminish as manufacturers rationalize their production.

TABLE 5

Changes in types of compound fertilizers

Per cent of total use

	1962	1965	1967
High-N	22	36	44
High-P	7	6	5
High-K	41	31	26
1-1-1 type*	4	6	7
Low-N	11	13	10

(*rough equal percentages of N, P_2O_5 and K_2O)

Liquid fertilizers

It is not easy to forecast how important liquid fertilizers will become in the U.K.; at present they are thought to supply about 2 per cent of our total fertilizer. Table 4 shows that liquid forms provided one-fifth of the world's nitrogen in 1965. Most early developments with liquids were in a few countries, principally U.S.A., but they are now commonly used. The advantages of liquids are:

1. They are easily and cheaply moved by pumping.
2. They can be distributed more accurately than solids.
3. They can be placed where needed in the soil by being injected under pressure.
4. Some forms of liquid N fertilizers (especially anhydrous and aqueous ammonia) are much cheaper than equivalent solids.

Some liquid fertilizers supply N, P and K; when tested in the U.K. these were found to be as effective as equivalent solids.[10] They are less concentrated than solid fertilizers and tend to be more expensive, so their use is not likely to increase as rapidly as liquids of other kinds. Increased use of liquids will depend on all the factors listed above, but particularly on the development of contract services, and on the total cost of materials *applied in the field.*

Problems for agricultural engineers

None of the changes likely in the nature, form and amount of solid fertilizers used will produce entirely new problems for engineers who make distributing machinery. In fact, their task has been made much easier in the last 20 years by the granulation of almost all fertilizers except basic slag. The quality and uniformity of granules is likely to be further improved; some basic slag has been produced in small granules, which are easy to spread and are said not to diminish the availability of phosphate to plants conferred by fine grinding. This does not mean that engineers can become complacent. Many papers have described the irregular delivery characteristics inherent in distributors and such machines perform badly especially when operated by unskilled workers. Small variations in an intended delivery rate are of small agricultural importance, but I agree with M. R. J. Holmes[11] that variations of much more than $\pm 10\%$ should not be tolerated.

Solid fertilizers are usually delivered by gravity (with some mechanical assistance) and are expected to flow like liquids through apertures and tubes; the most serious fluctuations in delivery are associated with their failure to behave as liquids. Liquids can be delivered much more accurately than solids because they can be pumped at intended rates and rarely cause blockages. Any difficult problems are likely to be with liquid nitrogen fertilizers. which are of three kinds:

(i) 'Non-pressure' solutions, usually made from ammonium nitrate and urea in the U.K. They often contain about 24% N.

(ii) 'Low-pressure' solutions of ammonia in water (29% N).

(iii) 'High-pressure' liquids, such as anhydrous ammonia with 82% N.

Liquids with above-atmospheric pressures must be injected below the soil surface to prevent nitrogen being lost to the air. 'Low-pressure' solutions are satisfactory when injected a few cm deep; anhydrous ammonia must be injected at least 15 cm deep in arable land. Injecting liquids deeply needs strong and expensive applicators and a powerful tractor. Figures given by F. V. Widdowson[12] and quoted in Table 6 show how the real cost of a fertilizer in the field is made of the cost of the material and the cost of applying it. The cheapest material to buy is made expensive if it is costly to apply. The cheapest solid form was 'Nitram' (ammonium nitrate) but the cheapest *applied* nitrogen was provided by aqueous ammonia. Anhydrous ammonia became more expensive because it cost more to apply.

TABLE 6

Approximate costs of applying 250 kg N/ha in December 1967

	%N	*Cost of fertilizer* £	*Cost of application per hectare* £	*Total cost* £
'Nitro-Chalk'	21	19.4	1.8	21.2
'Nitram'	34	17.0	1.2	18.2
Aqueous ammonia	29	12.0	2.2	14.2
Anhydrous ammonia	82	11.8	4.3	16.1
Liquid N	24	19.8	2.3	22.1

In experiments on arable crops both aqueous and anhydrous ammonia have been approximately as effective as ammonium nitrate, and there seems to be no serious mechanical difficulty in preventing loss of ammonia. But in experiments on grassland anhydrous ammonia was less efficient than solid N fertilizers, presumably because ammonia escaped from the cuts made by the injection tines. Although much more straight nitrogen is needed on grassland and more liquid fertilizers may be used on this crop, it seems that new machines will have to be developed, or existing machines used in different ways, before the cheapness of anhydrous ammonia can become an advantage to the grassland farmer. Perhaps the advantages of aqueous and anhydrous ammonia may be combined by delivering some water into the slit where the gas has been released.

THE AMOUNTS OF FERTILIZERS NOW USED ON U.K. CROPS AND CHANGES THAT ARE POSSIBLE

Table 7 shows what proportions of our total fertilizers are used on different kinds of crops. Cereals occupy a third of our arable land and receive about a third of all fertilizers used; other arable crops (potatoes, sugar beet, vegetables and animal-feeding crops) only occupy a tenth of the area but receive a fifth of the fertilizer. Grass occupies 60% of the land but receives only 40% of the fertilizer.

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TABLE 7

Percentages of fertilizers used on British crops in 1966

	Proportion of agricultural area %	N	P	K	*Total*
		Per cent of all fertilizers			
Cereals	32	40	33	40	38
Other arable	10	17	21	27	21
Grass	58	43	46	33	41

Current manuring of arable crops

The general summary in Table 8 has been derived from Surveys of Fertilizer Practice such as that described by Yates and Boyd.[5] The average recommendations for potatoes and sugar beet, based on field experiments testing fertilizers, are slightly *less* than the amounts farmers now use. Less nitrogen should be used on both crops; sugar beet, which is mainly grown on the richer soils, should receive less phosphate than it does.

TABLE 8

Average amounts of fertilizers used on important arable crops in 1965-1966

	N	P_2O_5 Kg/ha	K_2O
Winter wheat	88	56	51
Spring barley	66	41	46
Potatoes	164	181	248
Sugar beet	156	120	192

Cereals

The optimum amounts of N, P and K needed by cereals depend greatly on farming system and on reserves in the soil. The average amount of nitrogen needed varies in the following way:

Winter wheat needs from 30 kg N/ha for crops that follow leguminous leys, to 60 kg N/ha for wheat grown after potatoes, beans or peas, and to 150 kg N/ha for wheat that follows other cereals on old arable land. More fertilizer N is needed after a wet than after a dry winter.

Spring barley needs from 20 kg N/ha where the barley is grown after ploughing a leguminous ley, to 50 kg N/ha for barley after potatoes or beans, up to 120 kg N/ha where barley follows another cereal on old arable land.

The phosphorus and potassium needed also depend on soil and farming system. After potatoes, which receive much fertilizer and leave large residues, cereals may need none. Where cereal straw is made into manure that is used on the farm, and soils are 'satisfactory' in soluble P and K, 20 kg P/ha and 40 kg K/ha will be enough, but where straw is sold and soils are poor in soluble P and K, twice as much may be necessary.

Table 9 shows how greatly the amount of nitrogen used on cereals and grass changed in the eight years from 1958 to 1966, but there was no corresponding increase in the phosphorus and potassium used. These changes were caused by farmers using more 'high-N' fertilizers. Whereas nitrogen dressings are now much nearer to optimum, it is unfortunate that P and K have not increased; in fact for spring cereals there has been a slight decrease. The larger crops grown with more nitrogen will have certainly increased the P and K required.

TABLE 9

Changes in fertilizer use in U.K., 1958-1966

Average rates actually used where dressings were applied

	N		P_2O_5		K_2O	
	1958	1966	1958	1966	1958	1966
Cereals			Kg/ha			
Spring	36	69	48	41	50	46
Winter	45	88	55	56	49	51
Grass						
Temporary	50	89	75	69	59	49
Permanent	41	68	94	68	54	44

The *average* amounts of fertilizers now used on cereals (Table 8) are roughly correct. Some increase may be justified in future, perhaps of 20 to 30% in the average rates. There is an urgent need to adjust fertilizing to suit soil and farming system.

Grassland

There have been similar changes in grassland manuring (Table 9). Between 1958 and 1966 the amounts of N used on grass increased by two-thirds but the P and K applied diminished everywhere. These trends also reflect increased use of 'High-N' fertilizers; previously farmers used fertilizers richer in P and K and gave more dressings of straight nitrogen.

The yield from grassland in Britain is governed by nitrogen supply. Encouraging clover in the herbage by giving enough P and K will increase the N available to the grass, but clover alone cannot give enough nitrogen for maximum yields; where large amounts of N fertilizer are used, total yields in a year exceed those where clover is relied on to supply nitrogen. Under average conditions, where grass is cut regularly, at least 350 kg N/ha should be used in the season (the total amount being divided into 4 to 6 individual dressings, one being given for each cutting). When grass is grazed continuously, some of the nitrogen is used more than once in a season, because part of the N in the feed eaten is excreted; some of this is lost to the air, but much enters the soil and increases growth of the grass. For this reason less nitrogen is needed for grazed than for cut grass; but usually 250 kg N/ha will be justified for grazing by dairy cows. The amounts of phosphorus and potassium needed also depend on the way the grass is used and on the kind of soil. When grass is cut continuously all the P and K it contains is removed, and must be replaced to maintain soil fertility and yield. On rich soils some allowance may be made for the P and K the soil itself can supply, but reserves cannot be depleted indefinitely.

The amounts of fertilizers that are justified for grassland vary in the way shown in Table 10, which compares

TABLE 10
Fertilizers used on grass in 1966 and future targets

	Approximate present use		*Target, Kg/ha*	
	Fields dressed %	*Kg/ha used*	*Cutting regime*	*Grazing regime*
Temporary grass				
N	75	80	350	250
P	66	30	40	20
K	59	35	250	80
Permanent grass				
N	46	60	350	250
P	43	30	50	25
K	36	30	250	80

the present average use of N, P and K in England and Wales (determined by Surveys of Fertilizer Practice) with the amounts that it would be reasonable to use ('targets' in the Table). The targets are *very* approximate because correct optimum fertilizer dressings for grass cannot be stated unless the way grass will be used is known. But the figures show that grass for both cutting and grazing should receive several times as much N as is used at present and grass that is cut needs much more P and K than is now used. On average, grazed grass usually receives enough P, but more K may be needed on light soils.

Possible future trends

Arable crops other than cereals: the main need is to adjust fertilizing to farming system, soil and climate; the total amounts now used are enough.

Cereals: some increase in average nitrogen dressings is justified, and more care is needed in adjusting fertilizer to suit soil, farming system and season. A small increase in the average amounts of P and K used is justified.

Grassland: large increases in nitrogen manuring are needed. New techniques, and perhaps new materials, may be developed and liquid fertilizers will become more important. More potassium must be used where grass is cut and removed.

If we progress only half way towards the targets for fertilizing grassland (Table 10) during the next 10 years, we will then use about 1 million tons of N, 250,000 tons of P and 500,000 tons of K.

TRENDS IN METHODS OF APPLYING FERTILIZERS

Nitrogen fertilizers give large increases in yields of all crops except legumes and many experiments are being done to find the correct amounts of nitrogen and the most efficient ways of applying them. All mistakes in N manuring diminish profit: when too little is used, yields are small, when too much is given, some is liable to be wasted by winter leaching before another crop can use it. In contrast surplus P and K are not leached but retained by soil. Many recent experiments show that P and K reserves accumulated in soil from fertilizer residues are useful to following crops; also, soils rich in residues often give larger yields than poorer soils, however much fresh fertilizer is applied.[13] Differences between the returns from N and from PK, and these contrasts in the values of their residues, have several important implications.

Whereas P and K may be applied at the most *convenient* time, N *must* be applied when it will be most efficient. Often it will pay to fertilize separately with PK and to abandon the present practice of applying NPK compounds for all spring crops.

It pays to build up P and K reserves; after soils have been improved so that they contain 'satisfactory' amounts of soluble P and K, later dressings should be planned to maintain these reserves. Potatoes give worthwhile responses to P and K, even on rich soils, and they should always receive dressings in spring for 'direct action'. In contrast, maintenance manuring with P and K for other crops can be done when convenient during winter, and the N applied separately at the best time in spring.

Combine-drilling P and K fertilizers for cereals was often much better than broadcasting when poor soils were being reclaimed for cereal growing 25 years ago. These soils have now been improved by continued fertilizing and trials on them show only small gains, or none from combine-drilling P and K. On soils poor in nitrogen, drilling an NPK compound rich in N has often given 1-2 cwt more grain than broadcasting; farmers must decide whether such small gains make it worthwhile to use a combine-drill instead of broadcasting fertilizer before sowing separately with a wider drill, which is usually quicker.

Placement methods are usually most beneficial on poor soils and with small fertilizer dressings. Neither condition is now very common in British arable farming and special drills to place most of all the fertilizer used are likely to become less rather than more important. The only exception is that small dressings drilled with or near the seed may become more used as 'starter doses'. They give some insurance against slow growth when unfavourable weather follows sowing, and may be especially useful where most PK is put on as maintenance dressings in winter. (In USA these dressings are called 'pop-up' fertilizers). If starter fertilizers are used more for root crops, new drills may be needed; possibly the mechanisms being developed to apply granular pesticides near the seed may be adapted.

Nitrogen on grassland

The usual method of fertilizing grassland is to give a dressing of N in spring to produce extra growth for grazing, silage or hay. The relatively few farmers who use much N to control growth give further dressings before each cut or grazing. The cost of the fertilizer, however applied, is constant, but the cost of applying a given amount varies. Application costs can be large if special expensive machines are needed (as for anhydrous ammonia) or if labour has to be diverted from other urgent

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work. If a single dressing of a very concentrated fertilizer could last for a whole season, and if the work could be done when most convenient, application would cost much less than having to apply it on several occasions. The slow-acting solid fertilizers that have been successful in experiments are too expensive for grassland. Preliminary results published by F. V. Widdowson[12] suggest that large dressings of aqueous ammonia may last for a whole season but this needs confirming. Table 11 shows that a single

TABLE 11

Yields of dry grass produced by nitrogen fertilizers at Rothamsted in 1967

	Ammonia		*Nitro-Chalk*	
N applied Kg/ha	*Anhydrous*	*Aqueous*	*Single*	*Divided*
	Total yield of dry grass in year (Kg/ha)			
0	5800			
250	8780	9660	8660	11670
500	10290	12170	12170	12170

large dressing of aqueous ammonia was as effective as equivalent single or divided dressings of 'Nitro-Chalk', but with smaller amounts of N dividing the 'Nitro-Chalk' into several dressings given at intervals through the season gave larger yields. If dressings of ammonia can last for 10 months in many soils, as happened in this experiment, the use of this material will be encouraged.

EFFICIENCY OF FERTILIZERS

When fertilizers are used inefficiently their real costs are raised; this is often forgotten. Better methods of application may make manuring more efficient, and therefore cheaper. In the past most attention was given to the small short-term efficiency of phosphate, for rarely more than a quarter of a dressing is taken up by crops. The rest of the phosphate is precipitated in the soil; because these residues are *slightly* soluble they can be used slowly by later crops and experiments suggest that the whole of a dressing of P may ultimately be recovered. Hence, in time, phosphate can be completely efficient. The same is thought to be true for potassium applied to medium and heavy soils, but large repeated dressings are leached from light soils and wasted. On average of the crops and soils where measurements have been made, only about half of the N applied has been recovered. This small uptake means the cost per kg of N that entered the plant (and made it grow) was double the cost per kg of N that was bought. Much of the surplus N is lost by leaching in our climate and inefficiency of this kind increases the true costs of nitrogen manuring. The losses are serious from soils where N is easily leached, or where crops have small or diseased root systems that do not take up N efficiently. The large dressings of N now often recommended to help cereals overcome root disease, such as take-all, are used very inefficiently. Some recent figures are in Table 12. Nitrogen is more easily lost from Saxmundham than from Rothamsted soil; the true cost of the N actually

TABLE 12

Effects of percentage uptake of N-fertilizer on the cost of nitrogen used by crops

Assuming N costs 24 pence/Kg

	Per cent of N recovered	*N used Kg/ha*	*True cost of N used (pence/Kg N)*
Saxmundham			
Wheat with healthy roots	33	110	72
Wheat with diseased roots	12	70	204
Grass	40	220	60
Rothamsted			
Wheat with healthy roots	50	140	48
Grass	80	220	30

used by Saxmundham crops is larger, especially where wheat roots were diseased. These facts may lead to new methods of application, or to new kinds of fertilizers. If a larger proportion of the nitrogen dressing that is applied can be made to increase growth, less fertilizer will be needed for a given yield. Savings made in fertilizer materials may justify the extra costs of special application equipment, of slow acting materials, or of repeated dressings of straight N fertilizers (perhaps by aircraft). All of these possibilities are being explored in field experiments.

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Discussions to the Spring Open Meeting of the Institution held in Milton, Cambridge, in March 1968

MR P. G. BAKER-BEALL (Student, Clophall Farm, Sussex) said he would like to ask the speakers what the present state of knowledge was in this country concerning the effect on the crop of variation in *vertical* placement of fertilizer, in very general terms.

MR HOLMES replied that he thought it was fairly clear that in broad terms there was neither sufficient information about where the fertilizer ended after it had been applied to the surface of the soil, nor was it known in detail where it should have gone. He added that there was some information that one could put forward; for example there was information from the Grassland Research Institute at Hurley on deep application of nitrogen to grassland which referred to six to eight inches injection being shown to be advantageous, particularly under dry conditions. There was also information from Leeds on the value, again under dry conditions, of deep application of fertilizer for potatoes. Mr Holmes said these were the only two items of experimental evidence he could call to mind and he suspected that they were applicable only under dry conditions which would not be expected to apply as a general rule. There was fairly good reason to believe that under conditions of reasonably adequate moisture status in the soil root activity would be at its greatest in the biologically active part of the soil profile, i.e. to plough depth under arable conditions, or the top four or five inches of soil. Except under conditions of drought, the fertilizer should probably be not deeper than six inches but preferably worked in beyond the first inch or so, which might dry out quite sharply in short dry spells. In the absence of detailed evidence, one should be content under most conditions to get seedbed fertilizer reasonably well incorporated in the top few inches. For top dressings, particularly nitrogen on grassland, there was clearly no possibility of incorporation but nitrogen was fairly mobile and would get in a few inches once there was reasonable rain.

MR D. B. HARGREAVES ('Sisis' Equipment, Macclesfield), said it seemed to him that the figures in Mr Green's excellent and interesting paper were concerned with relating Mr Holmes' observations to the theoretical results of practical testing. It was not quite clear what in fact happened in the field as compared with what happened under the most critical forms of testing or even perhaps what was actually required. Mr Hargreaves suggested that a seventh question should be added to the six listed in Section 1 of Mr Green's paper and that conceivably it might read: 'Apart from the comparative results obtainable under specified trial conditions how does the machine vary from these results due to the more varying conditions of field use resulting from:

(a) Surface hardness and evenness of levels having effects similar to those measured by conventional bump test method;

(b) Windage causing variations of spreading pattern either of thrown or dropped materials;

(c) Irregular field shapes calling for special appreciation of the conditions affecting throwing patterns especially where required overlapping techniques already call for considerable driving skill?'

It is suggested that the coefficient of variation quoted in the paper should be subjected to an efficiency factor related to each type of machine, obtained by testing its delivery pattern under closely replicated field trials including the above physical conditions.

The hypothesis is offered that if a test machine could be provided with fertilizer components with no particle size variation and itself had no delivery variation characteristic, the unavoidable physical effects, such as the above, might be measurable to obtain by deduction a maximum theoretical efficiency factor. The need was to relate some of the theory more closely to what actually resulted in the field, as opposed to what happened in the best forms of test.

MR GREEN agreed with Mr Hargreaves that it was very desirable that a test report should give sufficient information to enable a user, or a potential buyer, to assess how the machine would perform in the field. He thought that the N.I.A.E. User Test Reports generally met this requirement. Although the distribution tests were carried out under ideal conditions the results did indicate how a machine would perform in the field. For example, the longitudinal test, with an artificial bump, showed how susceptible the machine was to bumpy conditions. Mr Green said that in his view the graph showing how the coefficient of variation varied with the bout width (Fig. 1) should be included in all test reports on broadcasting machines and in manufacturers' instruction books because it was the characteristic curve of the machine.

If the operator had this characteristic curve, he would not only know the evenness of distribution that he could expect to achieve when driving at any specified bout width, but he could also assess what driving errors he could tolerate and whether he could, in practice, work to these limits. Mr Green went on to say that it was possible that the overall efficiency of the spreading operation could be increased if the characteristic curve were used intelligently. The majority of manufacturers now recommended a bout width which, allowing for a $\pm$ 1 yard error, would result in the fertilizer being applied so that the coefficient of variation did not exceed $\pm$ 10%. But Mr Holmes had stated that for a low value crop a coefficient of variation of 15% was acceptable and, with some machines, this figure could be achieved by driving at

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FORTHCOMING EVENTS

* * *

A 'Plough-in' for Norfolk

The who'e range of ploughs on the British market will be displayed at a 'Plough-in' at Felmingham Hall, near Aylsham, Norfolk, on Wednesday, 2nd October from 10.30 a.m. to 4 p.m. These ploughs will be seen working, being pulled by the latest in British and imported tractors. In addition visitors will be able to compare the work rates and fuel consumptions of several anonymous outfits of different horse-power ratings, both 2-wheel drive and 4-wheel drive. The demonstrations are being organised by the Norfolk Farm Machinery Club.

* * *

Technical and Economic Problems of Mechanization of Agriculture in Developing Countries

The Institute of Tropical and Subtropical Agriculture, Prague, is arranging a Scientific Seminar for 23rd to 27th September, this year, to be held at the Agricultural College, Liblice, near Prague. The seminar, with the title 'Technical and Economic Problems of Mechanization of Agriculture in Developing Countries', will be formed in two sections, one economic and the other technical. Both sections will, however, combine on the first day to discuss problems of the formation of technical and economic staff for developing countries, and on the last two days for excursions to research institutes and production enterprises and for visiting the International Trade Fair in Brno. The organizers' address, for further information, is:

Institute of Tropical and Subtropical Agriculture,
Agricultural College, Prague,
Suchdol, Czechoslovakia.

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APPOINTMENTS WANTED—Members wishing to advertise under this heading will be charged 5s. per line reckoning 10 words to the line [minimum charge 20s.].

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Last date for the acceptance of Appointments advertisements for the next issue of the Journal: 30 September 1968

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The Institution of Agricultural Engineers

Penn Place Rickmansworth Herts.

Tel: Rickmansworth 76328

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ELECTIONS AND TRANSFERS

Approved by Council at its meeting 27 July 1967

ADMISSIONS

Member	*Overseas*	Ward, W. H.	South Africa
Associate Member		Gray, H. J. H.	Scotland
Associate		Annis, R.	London
		Baker, J. H.	Cambs
		Codd, H. E.	Lincs
	Overseas	Culverwell, W. H.	Zambia
		Frankish, J. D.	E. Yorks
		Gould, J. O.	Devon
		Greenwood, E. J. B.	Sussex
		Griffiths, D. H.	Worcs
		Hardy-Dover, R.	Cheshire
		Jones, D. B.	Warwicks
		Jones, F. E.	Shropshire
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		Kohler, B. H.	Beds
		Lowndes, D. S.	Glos
		Padfield, G. K.	Dorset
		Pemberton, J. D.	Warwicks
		Procter, R.	Lancs
		Rennie, D. V.	Scotland
	Overseas	Rowlson, P.	Nigeria
		Stewart, R. W. Mc	Scotland
		Stroud, D. A.	Oxon
		Wells, R. E. F.	Beds
		West, R. W.	Hants
Graduate		Goodhew, H. L.	Kent
Student		Adesuyi, S. A.	Beds
		Alabi, J. O.	Beds
		Curry, A. N.	Essex
		Davies, D. A. E.	Staffs
		Morgan, V. C. L.	Mon
		Morris, D. K.	Beds
		Thacker, J. R.	Leics

TRANSFERS

Member		Benfield, K. J.	Cambs
		Corbett, G. G.	Essex
		Hughes, E. W.	Wilts
Associate Member		Ellison, J. F.	Essex
		Jessup, R. W.	Suffolk
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		Spoor, G.	Beds
Graduate	*Overseas*	Hayward, A. R.	Canada
	Overseas	Riddle, M. J.	Uganda
Affiliated Organizations		West (Tractors Ltd)	
		Farm Machine Design Engineering	

ELECTIONS AND TRANSFERS *(continued)*

Approved by Council at its meeting 12 October 1967

ADMISSIONS

Member		Pettifer, D. W.	Lincs
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		Wood, J. G. M.	Northumberland

TRANSFERS

Member	*Overseas*	Gupta, S. B.	Ceylon
		Turner, J. C.	Oxford
		Ward, P. T.	Staffs

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ELECTIONS AND TRANSFERS *(continued)*

Approved by Council at its meeting 12 October 1967

Associate Member		Burlingham, D. H.	Worcs
		Calvert, J. T.	Yorks
		Collingwood, K.	Yorks
		Jarrom, J. W.	Leics
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	Overseas	Nasir, F. A.	Nigeria
		Senior, G. D.	Oxford
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Companion	*Overseas*	Nur El Huda, N. M.	Sudan
Graduate		Barron, N. A.	Berks
		Freer, C. S.	Herts
	Overseas	Mithani, K. A.	Uganda
		Morgan, V. C. L.	Mon
	Overseas	Thacker, G.	Malaysia
Affiliated Organization		Cleales Limited	

Approved by Council at its meeting 11 January 1968

ADMISSIONS

Associate Member	*Overseas*	Cervinka, V. I.	Ghana
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	Overseas	Saran, C.	USA
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		Hoskins, J. O.	Cards
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		Murray, P. J.	Berks
		Parkhill, C. D.	Kent
		Petty, D.	Yorks
		Theakston, T.	E. Yorks
	Overseas	Velauthapillai, P.	Ceylon
		Webster, A. J.	Staffs

ELECTIONS AND TRANSFERS *(continued)*

Approved by Council at its meeting 11 January 1968

Graduate		Christian, D. G.	Lincs
		Etherington, C. H.	Yorks
		Hartley, P. V.	London
		Heming, R. G.	Glos
		Jenkins, A.	Herts
		Lawton, J. N.	Devon
		McLean, F.	Lancs
	Overseas	Obika, C. O.	C.S.S.R
	Overseas	Le Patourel, C. E.	Rhodesia
		Peachey, B. P.	Glos
		Robertson, S. W.	Leics
		Sanders, G. B.	Essex
		Stevenson, R. M. A.	Surrey
		Thubron, J. A.	Cambs
		Turnbull, I.	Co. Durham
Student		Arksey, C. M.	E. Yorks
		Basford, W. D.	Beds
		Baskerville, P. H.	Staffs
		Bowerin, P. R.	Norfolk
		Briggs, G.	Lancs
		Day, M. J.	Beds
		Drew, R. O. A.	Essex
		Evans, R. T.	Anglesey
		Francis, M. H.	Sussex
		Godbold, M.	Suffolk
		Gould, A. M.	Warwicks
		Haynes, J. R.	Essex
		Holland, D.	Herts
		Inwood, P. A.	Norfolk
		Jackson, D. R.	Yorks
		Keevil, G. R.	Wilts
		Lamm, A. A.	Beds
		Levin, R. A.	Essex
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		McKee, F. A.	Lancs
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		Smith, R. H.	Devon
		Tilley, M. L.	Devon
		Tomlins, C. M.	Cheshire

TRANSFERS

Member	*Overseas*	Smith, W.	N. Nigeria

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ELECTIONS AND TRANSFERS *(continued)*

Approved by Council at its meeting 11 January 1968

Associate Member	.. .. ..	Barrett, F. M.	Surrey
	.. .. ..	Baynham, J. G.	Glos
	.. .. ..	Davidson, W.	Scotland
	.. .. ..	Edmunds, J. R.	E. Yorks
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	.. .. ..	Streatfield, R.	Kent
	.. .. ..	Williams, J. R.	Suffolk

Approved by Council at its meeting 9 April 1968

ADMISSIONS

Member	*Overseas* ..	Perera, L. R. L.	Ceylon
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	.. .. ..	Dodd, R. R.	Staffs
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	.. .. ..	Salisbury, S. J.	Berks
	.. .. ..	Sawers, D. W.	Suffolk
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	.. .. ..	Tomkinson, P.	Lancs
	.. .. ..	Turner, D. J. A.	Warwicks
	.. .. ..	Vowels, J.	Salop
Graduate	.. .. ..	Charlesworth, M. C.	Cornwall
	.. .. ..	Earley, J. A.	Wilts
	.. .. ..	Hamilton, W.	Scotland
	.. .. ..	Lucas, G. S. G.	Warwicks
	.. .. ..	Nwa, E. U.	Cambs
	.. .. ..	Redman, P. L.	Cards
	Overseas ..	Robertson, M. A.	Rhodesia
	.. .. ..	Vaughan, G. B.	Yorks

Approved by Council at its meeting 9 April 1968

Student	.. .. ..	Barnes, R. J.	Suffolk
	.. .. ..	Boden, C. E.	Essex
	.. .. ..	Desmond, R. A.	Hants
	.. .. ..	Fulton, R. N.	Scotland
	.. .. ..	Goord, R.	Kent
	.. .. ..	Heygate, C. N. S.	Warwicks
	.. .. ..	Jindani, M. A.	Scotland
	.. .. ..	Lee, C. O.	Beds
	.. .. ..	Murtland, R. J. W.	N. Ireland
	.. .. ..	Robinson, J. R.	Beds
	.. .. ..	Smith, E. T.	Northumberland
	.. .. ..	Smith, M. H. A.	Cornwall
	.. .. ..	Turner, P. T. D.	Oxford
	.. .. ..	White, C.	Devon
	.. .. ..	Wilkinson, M. A.	Beds

TRANSFERS

Member	.. .. ..	Smith, D. A.	Yorks
Associate Member	.. .. ..	Alcock, J. C.	Worcs
	Overseas ..	Bacchus, N. N.	Guyana
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	Overseas ..	Henchy, J. W. F.	Austrialia
	.. .. ..	Lowe, J. C.	Yorks
	.. .. ..	Partridge, R. T.	Wilts
	.. .. ..	Pettit, R. F. R.	Oxford
	Overseas ..	Quansah, E. K.	Ghana
Associate	.. .. ..	Fitton, S. G.	Wilts
Graduate	*Overseas* ..	Fynn, R. P.	Rhodesia
	.. .. ..	Giddings, R. M.	Northants
	.. .. ..	O'Dowd, E. T.	Bucks
	.. .. ..	Shepherd, W. R.	Essex

DISCUSSIONS TO THE SPRING OPEN MEETING
—from page 149

a larger bout width and still allowing for a ± 1 yard driving error. Mr Green asked whether manufacturers were imposing an unnecessary limitation on the operator by only recommending the lower bout, regardless of the crop to which the fertilizer was being applied. He realised that complicated instructions could be dangerous but he would like other peoples' views on this matter.

Regarding wind conditions, Mr Green said that in his paper (Section 3.1 (a)) he had stated that the performance of broadcasting machines was affected by blustery conditions but not significantly by steady winds up to 10 m.p.h. This statement was based on tests conducted in the field; regarding the test results quoted in Tables III, IV and V he would like to emphasize that these field tests were done in 1962, 1963 and 1964, and that the distribution figures had been calculated using the driving centres recommended at that time by the manufacturers. However, the transverse patterns obtained in these and later tests generally had conformed very closely to those obtained by the N.I.A.E.

Mr Green then dealt with the hypothesis suggested by Mr Hargreaves for arriving at a theoretical efficiency factor based on a machine being tested with a fertilizer having no variation in particle size. He said that it was an interesting suggestion but doubted whether it could be usefully developed. A closely graded fertilizer would be metered more precisely than a fertilizer graded between 1.5 and 3.5 mm. but, in practice, as stated in Section 4, the likely fluctuation in the feed rate would not increase the coefficient of variation by more than 1%. It would also be incorrect to assume that the performance of broadcasting machines would be improved by using a closely graded fertilizer. Numerous investigations had shown (Section 4) that the variation in the performance of broadcasting distributors was not sufficient to be significant if about 90% of the granules were between 1.5 mm. and 4.0 mm. Existing machines had been designed to suit this size range, and Mr Green said that experiments carried out by his company on some of these machines had shown that a very poor transverse distribution was obtained when a very closely graded fertilizer was used. Furthermore, another feature concerning broadcasting machines, which he had emphasized in his paper, was that the longitudinal variation given by these machines was small. This was because all the fertilizer did not leave the disc horizontally and there was a slight variation in the distance the particles were thrown, so that, in the longitudinal direction, there was a continual overlapping which resulted in a good distribution. If all the particles landed in a band about 6 in. wide behind the machine the situation would be similar to that for a full-width distributor which had a once-and-for-all chance of placing the fertilizer on evenly.

Mr K. H. Miller (Vicon Agricultural Machinery Ltd.) said he agreed entirely with Mr Green about the operator's problem in driving these machines; if one's operator was not good, then obviously one ran into considerable problems. For the operator to work efficiently the number of variables must be kept to a minimum. The concept of coefficient of variation would only confuse the operator unless he was very intelligent. It was therefore necessary to ensure that good patterns of distribution could be achieved but, at the same time, it should be made as easy as possible for the operator to cope with the machine.

Mr Green agreed that the whole problem was a matter of communication. The point he had tried to make was that one should not underestimate the intelligence of the farmer and that the farmer should be given as much information as possible. With the advice available from the National Agricultural Advisory Service and from the machinery and fertilizer manufacturers there was no reason why the farmer should not be given all the data, including the characteristic curve. If the farmer failed to understand it, then he could turn to the people who were paid to answer his questions.

Mr R. E. Goldsmith (British Field Products) said he wished to challenge Mr Miller's remarks about the operator. One must bear in mind that what the operator was there for was to set the machine and then get on with the job. Many of these machines provided no means of telling without looking backwards whether it was working properly or not. This was something the manufacturers should put right. Hydraulic motors had been used in some instances. On one machine that he had used there had been a lot of trouble with the drive that went to a rev. counter and in any case that was behind the operator. Unless the spinner was rotating, a uniform pattern could not be obtained. Mr Goldsmith said he wondered whether the user paid enough for his machine and he personally would have been quite prepared to pay another £50 for something on his spreader in front of the driver to tell him the machine was working properly. Did Mr Green feel that the standard of agricultural machinery used for spreading was good enough?

Mr Green quoted a sentence from Mr Holmes' paper to the effect that the design and operation of a fertilizer distributor must be a compromise between technical excellence and good commercial sense, and said that one of the machinery manufacturers' problems was finding out how much a customer was willing to pay for technical excellence. He was sure that the manufacturers represented at the meeting would be noting the questioner's willingness to pay another £50 for a satisfactory piece of equipment and that they would be trying to ascertain how many other users were of the same opinion. Mr Green said that there had been a great improvement in solid fertilizer applicators in recent years, and the machines were not expensive compared with the value of the fertilizer applied and the return the farmer expected from this operation—a farmer broadcasting 50 tons of fertilizer per year, worth about £1,500, would probably pay about £100 for the machine. The machines could be improved —any machine produced is already obsolete in the designer's mind—but the introduction of new and better machines obviously depended on the customer demand and the price they were prepared to pay.

MR H. FARMERY (Horstine Farmery Limited) referred to comments that had been made about the need for a sensible sowing chart. This was one thing that it was extremely difficult for manufacturers to give, simply because the materials to be applied varied in their weight/volume ratio. If some form of table could be established, involving a datum line indicating 'per 100' and then one got a weight/volume ratio for the material being applied, expressed as a percentage of datum, and printed it on the bag of fertilizer, the machinery manufacturers could give a sowing chart relative to this. This would involve the fertilizer manufacturer and machinery manufacturer getting together exactly as had been suggested earlier in this discussion, and it was long overdue.

Mr Holmes commented that he thought this would be a good thing but it gave rise to further problems. It was perhaps not only the weight/volume relationship that had to be considered but also weather conditions such as humidity and so on. While what this questioner had suggested might be a step forward, one could not be certain that it would be the complete answer. It raised the difficulty that had already been discussed as to how complex the instructions to operators should be.

MR I. J. FLEMING (Scottish Agricultural Industries Ltd.) said he wondered whether the problems were not even more fundamental than this. He had a shrewd suspicion that very many of the machines manufactured today were susceptible to wear in one place or another with the result that fertilizer might leak out on to, say, a spinning disc in an unexpected place so that in consequence the manufacturer's calculated spread pattern no longer held good. He suggested also that most of the tests were carried out as a matter of necessity in dry conditions and one could not always count on fine weather conditions in the field. Work often had to be done in wet, damp or humid conditions and this could materially alter the inevitable build-up of the fertilizer on the blades of the spinning disc and in the feed spout of the distributor. This in turn altered the position in which the material was put on the disc and so altered the pattern. Mr Fleming said he wondered whether some thought ought not to be given to ways by which these troubles could be obviated.

MR J. S. SELLEY (Atkinson's of Clitheroe Ltd.), referring to the subject of rev. counters, said he would congratulate the earlier speaker for obviously being in the vanguard by using a machine that had in fact a rev. counter installed. In the early days of this type of machine, it was represented as being a beneficial feature, but there was great anxiety as to what it would cost. The first attempt was one with an exposed drive, which was subsequently modified to an enclosed drive. As regards being able to observe the spreading operation without having to turn round in the tractor seat, Mr Selley said he did not know how one could achieve this other than having a spreader mounted at the front of the tractor. If it was merely a question of being able to check that a spinner was operating, a rev. counter mounted on the tractor could be considered, although it would be expensive and it might not cover all conditions. Believing a form of mirrors to be quite out of the question, he said that more information was needed generally on how to improve this aspect of operation. Mr Selley said he also wished to deal with a point concerning Figure 1 in Mr Green's paper. The chart of coefficient variation was very interesting; he recalled that in earlier days his own Company had published an instruction manual that set down for the farmer two bout widths of 21 or 32 ft. When their machines were put through tests at N.I.A.E., the latter's recommendation had been that it would be wiser and more useful to the farmer if he were given a single positive instruction with a reasonable guide table to work to, which should be as simple as possible. The Company had in fact accepted the N.I.A.E. recommendation of 21 feet. The type of chart in the paper would be a useful asset to the company or to be available to the agricultural engineer but not normally to the farmer who would be more confused than aided.

Mr Green said so far as caking was concerned, bags could be stored 40 bags high but in practice, for stability and general convenience, the height was usually limited to 30 bags high.

MR G. F. D. WAKENHAM (Ransomes, Sims & Jefferies Ltd.), asked whether in dealing with overlap Mr Byass had taken into consideration the effects of collision between one jet and another upon the spread pattern.

MR BYASS said that most of his information about this related to lower outputs than would normally be used in this context. He said he believed the effect would be relatively small even where quite a large volume of liquid was involved. There was still quite a large space between individual streams of drops and although some collision would modify the ideal pattern, the indications were that its significance was relatively small.

MR R. F. NORMAN (Fisons Farmwork Ltd.) said that the use of a patternator was not necessarily the best way of assessing the performance of a nozzle. With the volumes being considered, one should think of other techniques.

Mr Byass said he believed that a point about having deep troughs was that one obviously had to stop bounce with drops just as one had to stop it with solids. One must have some vertical partition of fields in order to make sure that a reasonable sample of what would hit an area was collected. The objection was that the nature of the actual surface to which the spray was applied would modify the pattern. The pattern obtained from the bare soil or from flat concrete would be different from that obtained when some foliage was standing on it. The difficulty was that when one moved away from a patternator—a box with sides to keep liquid volumes discrete from one to another—what would replace it? It would mean using something which was trying to reproduce the characteristics of all kinds of surfaces. Mr Byass believed that this would lead to other complications. Until one was discussing very fine limits of distribution, it was doubtful whether this was necessary or justified.

DR G. W. COOKE asked what Mr Byass thought about distribution where spray nozzles were not involved but where one required a stream of liquid not necessarily

Please turn to next page

DISCUSSIONS TO THE SPRING OPEN MEETING, 1968—*from previous page*

distributed in drops but dribbled on the ground, or perhaps feeding an individual coulter in the soil.

Mr Byass replied that to obtain uniformity it was better to have a lot of orifices close to the ground and close to one another so that the distribution problem was quite unimportant and one was spreading liquid evenly across the swath simply by pumping it along a tube with the right sort of orifices. He added that the only limitations he could suggest to this were firstly, that the more one had and the slower the movement the smaller each hole would be and a little more care would be needed to obtain the required accuracy. However, with the volumes being considered in this context, it was not a very great limitation. Secondly, one had to consider the limit of distribution and whether one could put all the material into say a ½ inch width band at 6 inch spacings. If this was a limitation, then one presumably had to get the jet of liquid to break up a little before hitting the soil.

In reply to a question concerning the ideal positioning of fertilizer for potatoes, Dr Cooke said that, had he been asked this ten years ago, he would have been absolutely exact and precise. The answer in those days would have been that putting it in bands beside the seed was best. Because it was difficult to place fertilizer in this way, little progress with satisfactory machines had been made and most farmers broadcast their fertilizer. Recent work at Rothamsted had suggested that with the very large dressings currently being used by farmers, broadcasting dressings and working them in well was more efficient than placement. Dr Cooke said that in the days when he had felt certain placed fertilizer was best, farmers used considerably less fertilizer on potatoes than was used today. With the rise in fertilizer concentration, more NPK was used and these dressings gave larger yields that repaid their cost provided they were broadcast and well worked into the soil. If such dressings were placed they did not give top yields. The recent experiments suggested that if one was going to be sparing in the use of fertilizer with potatoes, placement was necessary. Dr Cooke added that he did not think that one should be sparing with fertilizers for potatoes but large dressings should be distributed through the soil. Very large concentrations of placed salts checked growth but if the fertilizer was mixed with much soil, 'the sting' was taken out of it.

In reply to a question from Mr Farmery on the subject of toxicity, Dr Cooke said one should consider what happened when fertilizers were applied. Fixation usually meant the conversion of soluble to insoluble forms. Fixed nutrients although not completely useless, were very slow-acting. Water-soluble phosphate was quickly precipitated and became nearly insoluble. This reaction was fastest on chalky soils. Reasonable dressings of water-soluble phosphate therefore did not damage seed. The damage came from salts supplying nitrogen and from urea (which was not a true salt). The chloride in potash salts was damaging, though the potassium was safe, being 'fixed' by the soil. If fertilizers were to be placed in contact with seed small dressings of phosphate would be safe, but soluble potash salts might damage seed, and insoluble materials should be considered, such as the potassium metaphosphate, which had been developed by Scottish Agricultural Industries although not sold here.

MR T. SHERWEN (Agricultural Engineering Consultant) said that, from an engineering point of view, he would like to hear Dr Cooke's comments on the potentiality of liquid fertilizers, having regard to such considerations as storage and the present state of commercial development of liquid fertilizer applicators.

Dr Cooke said he thought there were many advantages in liquids from an agronomic point of view. Price considerations, plus the success that engineers and farmers were able to achieve in overcoming the problems of suitable application equipment and storage, would determine whether liquids would take a sizable part of the fertilizer market in this country. Dr Cooke believed that liquid fertilizers supplying NPK could not offer very much advantage because they were not very concentrated. They would cost much to store and needed specialized application equipment that would be used only a few times in the year. Contractors might find considerable advantages in applying liquids and the problems of seasonal application would be less if ways of using liquids that promote growth of grass for long periods can be found. There would then be more latitude in time of application and much more opportunity of using injection equipment for a longer period. This would diminish storage problems.

MR GOLDSMITH referred to Dr Cooke's remarks about accuracy of application of P and K not being so important when the dressings were intended to maintain soil reserves. This might give manufacturers of spreading equipment the wrong impression. One still had to apply the N and it was very important to apply that accurately in relation to crop maturity. In applying nitrogen to grassland for grazing, accuracy did not matter very much, but if one was growing grass for grass-seed production, accurate spreading of nitrogen was of great importance. Dr Cooke replied that he agreed completely that if cheap and not very accurate equipment was to be used, it should be applied only to the conditions in which accuracy did not matter very much and must not be extended to uses in which accuracy emphatically did matter.

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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